GROUP OF HIGH GRADE SHROPSHIRE EWE LAMBS, RAISED ON STATION FARM.

Average age, 13 months. Average weight, 127 lbs. Average weight wool shorn, 10 lbs.

NINTH ANNUAL REPORT

OF THE

Agricultural Experiment Station

OF THE

UNIVERSITY OF WISCONSIN

For the year ending June 30, 1892.

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☞ The Bulletins and Annual Reports of this Station are sent free to all residents of the State who request it.

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Office and Laboratories, in Agricultural Hall, University Grounds.
Experiment Farm with buildings, joins the college grounds on the west.
Telephone connection.

LETTER OF TRANSMITTAL.

EAU CLAIRE, Wis., October 1, 1892.

To His Excellency, GEO. W. PECK,

Governor of Wisconsin:

I have the honor to transmit to you herewith, in accordance with law, the Ninth Annual Report of the Agricultural Experiment Station of the University of Wisconsin.

Respectfully,

WM. P. BARTLETT,

President of the Board of Regents,

University of Wisconsin.

REPORT OF THE DIRECTOR.

In presenting the Ninth Annual Report of the Wisconsin Agricultural Experiment Station to the farmers of Wisconsin, I trust they will find therein evidences of continued earnest activity on the part of this Station in their behalf. That we have labored in only a very limited portion of the great field of agriculture is apparent at a glance of these pages, but no apology is deemed necessary. An experiment station is like an individual,— if a few things are to be well done, too much must not be attempted. A better realization of this has led to more concentration than ever before in the past. If the reader does not find within these pages something bearing on his favorite line of agriculture, he is asked to remember that our means are limited, and we aim to work on those problems which give helpful returns to the largest number of our farmers.

Investigations with Sheep.—No one will have to study Wisconsin's climate, soil, topography and markets long to realize that there are great possibilities for the mutton sheep industry. With our proximity to the best markets we have millions of acres of the finest sheep lands for pasture in the summer and furnishing abundance of nutritious proper food in winter. Portions of Wisconsin but little developed at this writing are pre-eminently adapted to sheep husbandry, and it is the ambition of the Wisconsin Experiment Station to be instrumental in assisting pioneers on these new lands to a proper understanding and a helpful ability to handle mutton sheep right from the start.

The reader will note that we speak of mutton sheep. The arid region of the United States and great areas on other continents are sufficient to produce all of the fine wool the world needs, at a lower cost than is possible on our

cultivated farms, each of small area. Why should our farmers then give their attention to fine wool production, while we have home markets constantly enlarging for fine mutton? But mutton of excellent quality can be produced with sheep that grow a fleece entirely satisfactory, whether the quality of the wool or the price per pound of the same is considered. Medium wool and good mutton can be produced from the same animal, and it is this sort of a sheep that will prove the most profitable on our farms.

Many of our farmers yet regard the sheep as a scavenger, and an animal that needs the least attention of any on the farm; the minds of such must undergo a revolution before successful mutton production by them is possible. The mutton sheep, the product of English farming, which is the best in the world, will stand no such rough treatment as will the patient, long suffering Merino, nor will mutton sheep bear handling in large flocks as is the case with fine wools. Care and attention must be given to these animals at all times, and it is just that care which brings profitable returns.

To those farmers who are looking for help in regard to the mutton sheep I am sure Prof. Craig's investigations will be read with interest and profit. His work in feeding and cross-breeding convey lessons not above the possibilities of our intelligent and progressive farmers.

Feeding Dairy Cows.—Mr. Woll's feeding investigations throw additional light on the subject of silage for dairy cows. The silo has come to stay in Wisconsin, and gradually our knowledge of how to get the most through it is being enlarged. With our dairy interests already of enormous extent the food supply of dairy cows becomes a problem of the highest importance. Our intelligent dairymen are making a great success of their work, and it would seem reasonable that the results obtained by leaders of this class should be made common knowledge among our people. The rations fed by some of our leading dairymen were first published in Bulletin No. 33, which proved one of the most successful publications ever issued by the Station the demand for the same being exceedingly large

and coming from all parts of the United States, and even other countries. In order to make the information still more available, and place it in more permanent form, we republish the essential parts of the bulletin in this report.

Dairy Investigations.—When Bulletin No. 24 in 1890 gave to our people a description of the Babcock milk test and how to operate it e naturally supposed that Dr. Babcock's work so far as this invention was concerned was practically completed, and that he would be at liberty to undertake other problems. To our surprise, and not with real regret, we have found that from that date until the present the Doctor's attention has been nearly altogether taken up with matters growing directly out of the test. Students have flocked to us by the hundreds for instruction in its use, and letters of inquiry have come literally by the thousand. Bulletin No. 24, with an edition of 10 000 copies describing the Babcock test was soon exhausted and the subject was again presented in Bulletin No. 31, in an edition of the same size. Our supply of this bulletin also having been exhausted, the matter will be republished again in bulletin form and is placed in this report in order to still further spread the information.

A new and interesting field for investigation is that made possible through the hundreds of our former dairy students scattered all over the state and elsewhere, operating cheese factories and creameries. Dr. Babcock's notes gathered from their reports show in condensed form much information which from the very nature of its source and reliability must possess merit.

Agricultural Physics.—That portion of the average rainfall of Wisconsin which is usually caught by the soil of our fields is barely up to the requirements of maximum crops, and in consequence the conservation of this moisture that it may be available for the plants as harvest time approaches, is a problem of the very highest importance to our farmers. There is no more intricate problem in the whole field of agricultural investigation than this one, and I am sure our farmers will follow Prof. King in his research not only with interest, but hearty wishes for his

success. The report he presents on the movement of water in the soil is worthy of thoughtful study.

Gradually as our knowledge of plant life enlarges we are learning that the cultivation of crops does not primarily mean the destruction of weeds, but that there is a higher purpose to be subserved. To have a profitable crop we must so nurture the plant that there may be a large and proper root growth. The illustrations and descriptions of the root growth of our several agricultural plants under varied conditions as presented in this report, will no doubt be studied with interest.

Mr. King continues his investigation of silo construction and presents an illustration of the round silo in use at the Station Farm.

Horticultural Work.—Our horticultural department has at last found a permanent home on that portion of the experiment farm covered by the hill side adjacent to the Washburn Observatory and including the level lands lying to the north skirting the shores of Fourth Lake. Nature has done much for us, and a more desirable location could scarcely be conceived. Prof. Goff has planted an experimental orchard on the hill side with its northern slope, and has gathered in orchard form promising varieties of hardy fruits from many sources. It seems useless to cumber these pages with lists of varieties planted, since the reader is interested only in results. Our horticultural work has not only been hindered heretofore from lack of suitable grounds, but is still suffering much for want of a horticultural building with forcing houses. Let us hope that those in authority seeing the need will not allow this department to go long unprovided. A most sightly place for a horticultural building is the grounds adjacent to Fourth Lake, or back on the hill side not far from the dairy school building.

Potato growing is a large industry in Wisconsin, and growers of this crop will be interested in Mr. Goff's efforts to find the best form of seed potatoes and work in fighting potato diseases.

In no direction have our experiment stations given more

helpful aid than in teaching the compounding of spraying mixtures and the proper application of the same. If our growers of potatoes and apples whose crops are affected with fungus and insect diseases will only follow the directions given in this report for making and applying these mixtures, much good will be accomplished. Farmers and gardeners are apt to look with suspicion upon these remedies, regarding it as beyond their ability to make and apply them. While it requires intelligence and some skill to use the remedies successsfully, they are not half so difficult as they first seem, and sharp competition will drive our progressive people into their use and leave others with poorer crops and diminished profits

Sugar Beet Culture.—For three seasons past a careful study has been made of the possibilities of Wisconsin soil for the production of sugar beets. Mr. Woll presents a summary of the results and his figures show that Wisconsin occupies a very favorable position, both in respect to the amount of sugar contained in the beets and the yield of roots per acre. While we can grow good sugar beets with a large yield of roots per acre there are difficulties of a serious nature confronting us. The thinning and weeding of the beets necessitates a very large amount of field labor in the early midsummer. Again, the beets do not mature until early in September and severe winter soon sets in, making the period for manufacture extremely short. There are two sugar beet factories now in operation in Nebraska, where the general conditions are very much the same as in Wisconsin; if they succeed the information we have gathered will be highly useful to any enterprise that may start up within our borders. Should they fail there seems little use of putting money into the same venture in this state.

I regard the production of all the sugar consumed by our people as one of the greatest agricultural problems now before us, and if anything can be done by the Wisconsin Experiment Station to assist in the matter it will be cheerfully undertaken upon solicitation. On three separate occasions we have been consulted by parties proposing to

start sugar beet factories, in one instance the matter having gone so far as the capital having been subscribed and a small portion of the money paid in. In each case inquiry showed that the people were given to understand that cheaply built factories would give profitable returns. In such cases we always discouraged the movement and believe that had our advice not been taken, the money invested would all have been lost. The capital required to construct and operate a beet sugar factory runs into the hundreds of thousands of dollars, and not a dollar should be invested until a considerable period has been spent in studying the whole subject, including the adaptability of the soil to the beet plant, and the willingness of the farmers to grow crops equal to the capacity of the factory. Wisconsin has experienced two failures in beet sugar factories, and this should teach caution.

Composition of Feed Stuffs.—The subject of the chemical composition of feeding stuffs is one that is exciting more and more interest among farmers who express themselves as having gained great help therefrom. Mr. Woll continues instruction in this direction, and has materially increased the table showing the composition of feeding stuffs over that in former reports. The lithograph in colors should enable the reader to institute ready comparisons in regard to the relative composition of the several articles there named. It may be well to remind the reader that while the chemist and physiologist have done a vast amount of work in studying the composition, digestibility and feeding value of our various stock foods, from the very necessities of the case the figures they present are crude and far from being as correct as they should be or as the novice at first supposes. Granting this, it is nevertheless true that properly used these figures are helpful and lead the stockman to a more careful consideration of the dietaries of the animals under his care.

The Dairy Building.—The new dairy school building, named the Hiram Smith Hall in honor of Wisconsin's veteran dairyman who labored most faithfully for the advancement of this great interest, and to whose efforts the

founding of the dairy school was largely due, is now completed and has been filled to the limit with students. The arrangement of the several rooms and the facilities for instruction and investigation, are extremely satisfactory and our students are flowing out over the state making use of the instruction they have received in scores of creameries and cheese factories.

It is with much pleasure that we acknowledge the receipt of a fine life size bust crayon portrait of Hiram Smith, from his daughter, Mrs. H. K. Loomis, of Sheboygan Falls. This portrait will be found in the office of the Hiram Smith Hall.

Correspondence.—As the work of the Station becomes better known and our farmers learn how to make use of its facilities, there has been a gradual growth in correspondence until now it amounts to thousands of letters annually, the consideration of which requires no small part of the time of the Station force. As in the past we stand ready to assist our agricultural people in all possible ways in their laudable effort to place Wisconsin's agriculture on a higher plane.

Reports and Bulletins.—Of reports and bulletins already issued we still have a small supply of the following:

Sixth Annual Report, for the year 1889.

Seventh Annual Report, for the year 1890.

Eighth Annual Report, for the year 1891.

Bulletin No. 16. A New Method for Determining Fat in Milk (Short's Test), July, '88.

Bulletin No. 19. Notes on Ensilage, April, '89.

Bulletin No. 21. Comparative Value of Warm and Cold Water for Milch Cows in Winter, October, '89.

Bulletin No. 22. Report on Oats, Barley and Potatoes for 1889, January, '90.

Bulletin No. 23. Prevention of Apple Scab, April, '90.

Bulletin No. 25. Feeding Bone Meal and Hard Wood Ashes to Hogs Living on Corn, October, '90.

Bulletin No. 26. Sugar Beet Culture in Wisconsin, January, '91.

Bulletin No. 27. The Feeding Value of Whey, April, '91.

Bulletin No. 28. The Construction of Silos, July, '91.

Bulletin No. 29. Creaming Experiments, October, '91.

Bulletin No. 30. Sugar Beet Experiments in Wisconsin for 1891, January, '92.

Bulletin No. 32. Feeding Grain to Lambs, July, '92.

Copies of these reports and bulletins will be sent upon request so long as they last.

The reports and bulletins of this station are printed by the state and will be sent upon application to all parties in the state who wish to receive them. Our mailing list already embraces many thousand names and is steadily growing.

FEEDING GRAIN TO LAMBS BEFORE WEANING.

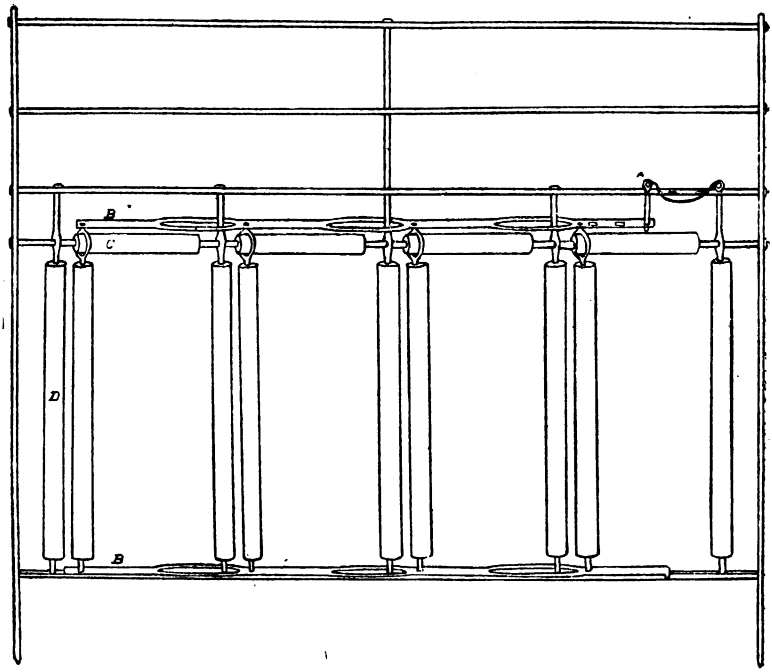
JOHN A. CRAIG.

The feeding of lambs is generally carried on under one of the three following systems: The most common method is to let the lambs and their dams do as well as they can on pasture without grain. This method of management is followed mostly where sheep are kept on rough lands, and the chief product from the flock is wool. Where more attention can be given to the welfare of the flock the rule is to follow another practice, the distinctive feature of which is to feed the grain directly to the lambs and none to the ewes. This would seem to be the best method to follow under conditions that would afford a fair market for prime lamb and mutton. Under the third system, which is of a more forcing nature, both the ewes and lambs are fed grain. This plan has been generally adopted by those that buy ewes in the fall each year, rear a crop of lambs from them and then sell both the ewes and the lambs. It is adopted also by those that rear very early lambs, for it is thought that feeding grain to the ewes forces the maturity of the lamb. The chief purpose of this is to discuss these methods in the light of the facts we have obtained from an experiment undertaken with the view of finding out which system would be most profitable under the conditions of general farming.

THE METHOD OF FEEDING LAMBS GRAIN.

To feed grain to lambs it is best to have a part of a pen or corner of a field fitted for this purpose, so that the lambs may have a special place to feed. In a pen in the shed a corner may be easily divided off and in the field a

sheltered place, where the flock may be in the habit of gathering, should be selected. The simplest way of making a lamb creep is to take two strips, long enough to reach across the corner of the pen and strong enough to hold stiffly the narrow upright pieces that should be nailed to them about one foot apart at first. As the lambs grow the spaces between the uprights must be increased. An ingenious and very useful construction specially devised for this purpose is shown in the accompanying engraving.



A LAMB CREEP.

A.—Peg for shifting sliding frame.
B.—Sliding frame.
C.—Horizontal rollers.
D.—Upright rollers.

For an acquaintance with this device we are indebted to William Watson, of Turlington, Nebraska. It can be readily seen from the illustration how the size of the opening may be easily changed by shifting the peg at A. By doing that the sliding frame, B, is moved and that throws the upright rollers, D, closer or farther apart. The frame work of

the creep is made of light, flat, iron strips. The upright and horizontal rollers are made of hard-wood about two inches in diameter. The creep is three feet four inches high and four feet six inches wide. The stationary, upright rollers are one foot apart and two feet long. The illustration shows the creep opened as wide as possible. The two end strips of iron are extended so that the creep may be readily driven into the ground, and by running a board partition from either side it is easy to separate small apartments for the lambs, either in the sheds or fields.

Inside of the apartment for the lambs we have a small wooden trough that is specially suited for feeding lambs. It differs from an ordinary grain trough for feeding grain to sheep in that a narrow strip runs along the top of the trough about eight inches above the centre of the part of the trough that holds the grain. This is to keep the lambs out of the trough. In crowding for their feed they would get into the trough with their feet and spoil the food if it were not for this arrangement.

OUTLINE OF THE EXPERIMENT.

We selected forty ewes that had fifty-six lambs at foot, and these we divided into four lots; thus putting in each lot ten ewes and fourteen lambs. The ewes were mostly high graded Shropshires. A few Merino and some first cross Shropshire-Merinos were included, and these were distributed as evenly as possible among the lots; so that the breeding of the ewes, compared in lots would be uniform.

The lambs in the lots were quite even in respect to age. The average age of those in Lot I was twenty-seven days, while those in Lots II, III and IV all averaged thirty-two days. In each lot we were careful to put the same number of twins. And the fact that there were four instances of twins in each lot with only six single lambs should be remembered in considering the gain made by each lamb. The most of the lambs were sired by a Shropshire, though some of them were got by a Southdown, and a few others

by a Dorset. The breeding of the lambs is fully given in the tables that appear in the appendix.

The plan of the experiment was to arrange the feeding so that the same grain mixture would be fed to all the lots excepting Lot IV. In Lot I the lambs and ewes both received the grain mixture, in Lot II only the lambs were fed the grain, in Lot III only the ewes were given grain, while in Lot IV neither the ewes nor lambs received any grain.

The following arrangement of the lots will place the differences in the feeding in strong contrast:

Lot I—Ewes fed grain; lambs fed grain.
Lot II—Ewes no grain; lambs fed grain.
Lot III—Ewes fed grain; lambs no grain.
Lot IV—Ewes no grain; lambs no grain.

In this way we hoped to find out if it paid to feed grain, and if so would it be best to feed it to the lambs, to the ewes, or to both. The lambs of Lot I were given all the grain they would eat. At first the ewes of that lot were fed one pound per head daily, but later on, when they were put on good pasture, this was reduced to one-half pound per head per day. In Lot II the lambs were given all they would eat of the grain mixture. In Lot III the grain ration of the ewes was one pound per head daily, but this was afterwards reduced to one-half pound per head per day.

The grain mixture was the same for all the lots and alike for both ewes and lambs. During the first three weeks it consisted of one part oil-meal and three parts bran. Then it was changed to one part crushed corn, one part oil meal and two parts bran. As the experiment was started shortly before pasture was ready for grazing, the ewes were fed considerable hay of a poor quality. This as well as all the other food consumed, has been charged against them and appears in full in the tables that are given in the appendix.

RESULTS OF THE EXPERIMENT.

The leading feature of this experiment is to be found in the evidence it offers on the practices of feeding grain to ewes and to lambs. For the purpose of making the comparisons clear it is necessary to arrange the lots into groups and combine the groups into tables of the principal data.

1. *Feeding Grain to the Lambs.*

To determine whether it paid to feed the lambs grain or not, it will be best to group the lots together in the following manner:

GROUP I.	Lot I.	Ewes fed grain; lambs fed grain.
	Lot III.	Ewes fed grain; lambs no grain.
GROUP II.	Lot II.	Ewes no grain; lambs fed grain.
	Lot IV.	Ewes no grain; lambs no grain.

The first table which follows has been compiled in conformance with this. It will be noticed that the four lots have been arranged into two groups. In Group I containing Lots I and III, all the ewes were fed grain and given like care. The difference in the management of these lots lies in the fact that in the instance of Lot I the lambs received grain, and in Lot III they did not. In Group II in the same table the ewes of both lots in it were not fed grain, and the only difference made in the management of the lots was that the lambs of Lot II were fed grain and those in Lot IV were not fed grain.

I. Table comparing grain fed lambs with those that were not fed grain before weaning.

DATA SUMMARIZED.	Group I. In these lots ewes were fed grain; lambs given grain (Lot I) and no grain (Lot III).				Group II. In these lots the ewes were not fed grain; lambs grain (Lot II) and no grain (Lot IV).			
	Lot I. lambs (14) grain; ewes (10) grain.	Lot III. lambs (14) no grain; ewes (10) grain.	Differences in favor of		Lot II. lambs (14) grain; ewes (10) no grain.	Lot IV. lambs (14) no grain; ewes (10) no grain.	Differences in favor of	
			Grain.	*No grain.*			*Grain.*	*No grain.*
Weight at beginning: 14 lambs	293.25 lbs	307.25 lbs	....	14 lbs	339.25 lbs	318.75 lbs	20.5 lbs	....
Weight at ending: 14 lambs	725.5 lbs	703. lbs	22.5 lbs	....	789.75 lbs	714.5 lbs	75.25 lbs	....
Gain in 10 weeks: 14 lambs.	432.25 lbs	395.75 lbs	36.5 lbs	....	450.5 lbs	395.75 lbs	54.75 lbs	....
Average weekly gain per lamb	3.08 lbs	2.82 lbs	.26 lbs	....	3.21 lbs	2.82 lbs	.39 lbs	....
Loss of ewes	80.9 lbs	46.6 lbs	....	34.3 lbs	111.1 lbs	45.9 lbs	....	65.2 lbs
Cost of food eaten by ewes	$5.42	$6.05	62 cts	....	$2.39	$2.10	....	29 cts
Cost of grain eaten by lambs	$3.16	....	....	$3.16	$3.50	....	....	$3.50
Estimated difference in market value of lambs	....	....	$7.63	....	....	....	$9.06	....

To decide whether the results of this experiment show that it pays to feed grain to the lambs, it is only necessary to contrast the data of the first table. Comparing Lot I with Lot III, between which the only difference in feeding is that the former had grain and the latter had not, we find that the 14 lambs of Lot I gained a total of 432.25 lbs. in 10 weeks, while the lambs of Lot III, without grain gained 395.75 lbs. in the same period. The difference in gain is 36.5 lbs. in favor of the grain fed lambs. The comparative cost of the food eaten by Lot I, including the 443.25 lbs. of grain eaten by the lambs and the 441 lbs. grain and 922 lbs. hay eaten by the ewes, amounts to $8.58. The comparative cost of the food of lot III, including the 583 lbs. of grain and 759.25 lbs. of hay eaten by the ewes, was $6.05, leaving a balance against the grain fed lambs of $2.53 to be compensated for by the extra gain of 36.5 lbs. To decide upon the differences in the market value of the lambs, we had Mr. Hoven, a local buyer, who is accustomed to estimating the value of sheep in this way, examine them. It was his statement that he would pay ¾ of a cent more per pound for the lambs that had been grain feed than for those that had not received any grain. At such a valuation he asserted that the grain fed lambs would be much the cheaper to him as they would dress better and as lamb they would sell more readily than the others. Allowing such a difference between them, it will be moderate to put the price of the grain fed lot at 6¾ cents per pound and that of those that had no grain at 6 cents per pound. Elsewhere in this report in the statement given relating to the value of lambs in the different months of the year, it will be noticed that the average price of lambs on the Chicago market during the past two years has been 9⅓ cents per pound. As the total weight of the grain fed lambs was 725.5 lbs. and that of the lambs that had no grain was 703 lbs., it will be found that the grain fed lot was worth $7.63 more than those in the lot that had no grain. In this estimate the 14 pounds that Lot III had to their advantage at the begining of the experiment is deducted. As it cost but $2.53 to

produce this difference of $7.63 it seems clear that it paid to feed the lambs grain.

A comparison of the lambs in Lots II and IV will make the same result clear. In both these lots the ewes were given the same feed, and the only difference between the lots is that in one, Lot II, the lambs were given grain, and in the other, Lot IV, the lambs were not given grain. In the table the gain of the grain fed lambs is given as 450.5 lbs.; while that of the lambs that were not given grain is 395.75 lbs.; a difference to the credit of the grain lot of 54.75 lbs. The same difference in the market value exists as in the instances already discussed. Estimating the differences in value in the same way we find that the lambs of Lot II that had grain were worth $9.06 more than the lambs in the other lot. The cost of feeding the ewes was almost the same, there only being a difference of 29 cents between those of the lots; so that it may be said that the 488.75 lbs. of grain that the lambs of Lot II ate was the chief agent in producing the difference in their gain and value. The comparative cost of the grain fed to these lambs was $3.50, to which may be added the 29 cents extra cost for the feed of the ewes. The comparison of these lots, in which a difference in cost of $3.79 produces a difference of $9.06 in market, indicates that it is profitable to feed the lambs grain before they are weaned.

Aside from the direct profit made in feeding lambs grain before they are weaned, there is another good reason for the practice. The lambs that have received grain previous to weaning will not suffer any loss of weight because of the weaning, while the same cannot be said of those that have had no grain. As a result of the grain feeding they gradually become able to feed themselves, and when the weaning period arrives they do not fret.

It is but right to say that the pasturage given these lambs influenced the results. The ewes and lambs of all the lots had excellent pasturage, and the most of the period it was good clover. So that the results shown in favor of grain feeding were obtained under the best conditions that could be given to the lambs that did not receive any grain.

II. FEEDING GRAIN TO THE EWES.

To throw as much light as possible on the question as to whether it paid to feed the ewes grain it will be advisable to regroup the same lots. The following arrangement will make the differences in the feeding of the ewes clear:

GROUP III.	Lot I:	Ewes fed grain; lambs fed grain.
	Lot II:	Ewes no grain; lambs fed grain.
GROUP IV.	Lot III:	Ewes fed grain; lambs no grain.
	Lot IV:	Ewes no grain; lambs no grain.

In the second table submitted on the next page the foregoing arrangement has been adopted. In the third group the lambs in both lots received grain, but in the one lot the ewes received grain and in the other they did not. In the fourth group in the same table the lambs were given the same care, as they did not have any grain given them, but the feeding of the ewes differed inasmuch as those of Lot III were fed grain and those of Lot IV were not.

II. *Table Comparing the Lambs of the Grain Fed Ewes with the Lambs of Those That Were Not Grain Fed.*

Data Summarized.	Group III. In these lots the lambs were fed grain. Ewes grain (Lot I) and no grain (Lot II).				Group IV. In these lots the lambs were not fed grain. Ewes grain (Lot III) and no grain (Lot IV).			
	Lot I. ewes (10) grain; lambs (14) grain.	Lot II. ewes (10) no grain: lambs (14) grain.	Differences in favor of		Lot III. ewes (10) grain: lambs (14) no grain.	Lot IV. ewes (10) no grain: lambs (14) no grain.	Differences in favor of	
			Grain.	*No Grain.*			*Grain.*	*No Grain.*
Weight at beginning: 14 lambs....	293.25 lbs.	339.25 lbs.	....	46. lbs.	307.25 lbs.	318.75 lbs.	....	11.5 lbs.
Weight at ending: 14 lambs............	725.5 lbs.	789.75 lbs.	....	64.75 lbs.	703 lbs.	714.5 lbs.	....	11.5 lbs.
Gain in ten weeks: 14 lambs............	432.25 lbs.	450.5 lbs.	....	18.25 lbs.	395.75 lbs.	395.75 lbs.	....	....
Average weekly gain per lamb..	3.08 lbs.	3.21 lbs.	....	.13 lbs.	2.82 lbs.	2.82 lbs.	....	... .
Loss of ewes................	80.9 lbs.	111 lbs.	30.1 lbs.	....	46.6 lbs.	45.9 lbs.	....	.7 lbs.
Cost of food eaten by ewes	$5.43	$2.39	....	$3.04	$6.05	$2.10	....	$3.95
Cost of grain eaten by lambs............	$3.16	$3.50	34 cts.	....	....	....	....	....
Estimated difference in the market value of lambs........................	....	....	....	....	....	....	....	....

As to whether it pays best to feed the lambs the grain, or the ewes, or both, the facts are decisive. In no instance was there any apparent benefit to the lambs from feeding the ewes grain. The conduct of the lambs is the main consideration of the experiment, for the value of a pound of gain made by a lamb is worth fully double what a pound of gain would be worth when made by an old ewe. And the ewes would on fair pasture quickly add to their weight after weaning what they had lost while suckling their lambs. It is to be remembered that previous to lambing the whole of the ewes in this experiment had been fed grain, and the majority of them were in good condition. The ewes in Lot I, as may be seen in the appendix, ate 441 lbs. of grain, and the lambs of that lot ate 443½ lbs. of the same grain mixture. In Lot II, where the ewes did not receive any grain, the lambs of that ate 488¾ lbs. of grain, and they gained 18¼ lbs. more than the lambs of Lot I. In addition the cost of food in Lot I was $2.70 more than that of Lot II. From this it will be seen that the lambs in the lot containing the ewes that were fed grain, did not gain as much as the lambs of the lot in which the ewes did not receive any grain. The ewes of Lot I, however, lost only 80.9 lbs. in flesh, while those of Lot II lost a total of 111 lbs. during the period. That difference is of little practical value for the reason before stated.

By comparing the results obtained from Lots III and IV, as in group IV of the second table, the fact that it does not pay to feed grain to ewes is again illustrated. The only difference in the management of these two lots was that the ewes of Lot III received grain and the lambs did not; while in lot IV neither the ewes nor lambs received any. The lambs of Lot III gained a total of 395¾ lbs., and their dams ate 583 lbs of grain, making the total cost of the food eaten $6.05. The lambs of Lot IV made a total gain of 395¼ lbs., and the cost of food eaten by their dams was $2.10. The lambs of Lot IV gained the same as the others, and this at much smaller cost.

SUMMARY OF RESULTS.

1. From the results of this experiment it is clear that it pays to feed the lambs grain before they are weaned. Fourteen lambs that were fed grain made an increase in gain of 36.5 lbs. in ten weeks, over that made by fourteen lambs that had no grain. The extra cost of food for the ewes and lambs was $2.54, and the difference in the market value of the lambs was estimated to be $7.63. In two other lots, with fourteen lambs in each, those that received grain made an increased gain of 54.75 lbs. at an expense of $3.79, and the estimated difference in market value amounted to $9.06. In the lots that have been compared the ewes had similar feed and care given them and the differences in the amounts of food that they ate are charged against the lambs. In a similar experiment conducted in 1891 it was found that the three lambs that had been fed grain before weaning made an excess gain over the lot that had no grain of 25 lbs at a cost of 56 cts. The results of two experiments, giving us data from sixty-four lambs, endorse the practice of feeding the lambs grain previous to weaning time.

2. In none of the instances did it pay to feed the ewes grain. The lambs suckled by the ewes that were not fed grain, on good pasture made as great a gain as those of the ewes that were given grain. The expense of feeding grain to the ewes was $3.95, and no corresponding benefit was derived from it.

COTTONSEED MEAL COMPARED WITH OIL MEAL FOR FEEDING LAMBS.

JOHN A. CRAIG.

The lambs used in this experiment were Shropshire grades of good quality. They were uniform in appearance and previous to this time had received like management. They were weaned July 9th, when slightly over three months old. After a week of preliminary feeding they were started on the experiment July 16th, and continued on it until September 24th, a period of ten weeks. The ten lambs were divided into two lots of five. At the beginning of the experiment each lamb in Lot I averaged 55.1 lbs. and those in Lot II averaged 53.1 lbs. It will be seen from these figures that the lots were very similar in weights. Both lots were pastured on the same field. The difference in feeding was as follows:

Lot I, 1 part *oil meal*, 2 parts corn meal, by weight; pasture.

Lot II, 1 part *cottonseed meal*, 2 parts corn meal, by weight; pasture.

Both lots were fed all the grain they would eat with a relish. While each lot always ate the grain given them yet the lambs of Lot I receiving the oil meal mixture were more eager in eating theirs.

GAIN OF LAMBS.

During the progress of the experiment one of the lambs in Lot II died, so that it is but possible to compare the lambs of each lot in their average weekly gain. The following table is summarized from the fuller statements of the weekly progress of the lambs which are given in the appendix.

Table Comparing the Lambs Fed Cottonseed Meal with Those Fed Oil-meal:

Data Summarized.	Lot I. 1 part oilmeal 2 parts corn-meal.	Lot II. 1 part cotton-seed meal 2 parts corn-meal.	Differences in favor of	
			Oilmeal.	Cottonseed meal.
Average weight at beginning..................	55.1 lbs.	53 1 lbs.	2 lbs.	.. ..
Average weight at ending..	88.1 lbs.	82.1 lbs.	6 lbs.	. .. .
Average weekly gain during 10 weeks	3.30 lbs.	2.95 lbs.	.35 lbs.	....
Grain eaten..........	432.5 lbs.	346 5 lbs.	....	86 lbs.
Comparative cost 100 lbs. gain.....	$2.09	$2.25	16 cts	....

A comparison of the lots shows their standing to be as follows:

Lot I, (Oil meal) ate 432.5 lbs. grain; weekly gain of each lamb 3.30 lbs.

Lot II, (Cottonseed meal) ate 346.5 lbs. grain; weekly gain of each lamb 2.95 lbs.

It may be noted that the weekly gain of 3.30 lbs. for each lamb in Lot I is a high rate. The weekly gain of each lamb in lot II being 2.95 lbs., makes a weekly difference of slightly over one-third of a pound gain in favor of the lambs that were fed the oil meal mixture.

COST OF GAIN.

When the costs of these gains is considered, the balance in favor of the oil meal is enlarged. As may be seen in the statement given at the back of this bulletin, the lambs of Lot I ate 432.5 lbs. of the oil meal mixture, and those of Lot II, getting the cotton seed mixture, ate 346.5 lbs. Valuing corn meal at $14 per ton, oil meal at $20 per ton, and cottonseed meal at $25 per ton, which are average prices, the comparative cost of one hundred pounds gain would be:

Lot I (Oil meal) 100 lbs. gain cost $2.09.

Lot II (Cottonseed meal) 100 lbs. gain cost $2.25.

These figures show a difference of 16 cents per one hundred pounds gain in favor of the lot receiving the oil meal mixture.

SUMMARY OF RESULTS.

The results of this trial show:

1. For feeding lambs, a grain mixture of oil meal and corn meal gave better results than a grain mixture of cottonseed meal and corn meal.

2. The lambs fed the oil meal made a greater gain than those receiving the cottonseed mixture. During the ten weeks' trial the lambs fed the oil meal ration each made a weekly gain of 3.30 lbs., while those getting the cottonseed ration each made a weekly gain of 2.95 lbs.

3. The oil meal ration was, in addition, cheaper; for the lambs so fed made 100 lbs. gain at a cost of $2.09, while those getting the cottonseed ration made 100 lbs. gain at a cost of $2.25.

SHEARING WETHERS BEFORE FATTENING.

JOHN A. CRAIG.

This experiment is the second in a series undertaken to test the profit there is in the practice of shearing wethers before fattening them, and to indicate, if it prove to be a profitable practice, the best time for shearing.

In the first experiment made in this direction, conducted last year, the wethers were shorn on December 12th. It was then found, on the conclusion of the experiment at the end of eleven weeks, that the wethers once shorn gave the most profitable returns. The three wethers that had been shorn twice, once in December and again in April, gave in the two clippings 28 5 pounds of unwashed wool; while those that were shorn once, April 24th, gave a total clip of 32.7 lbs. or 4.2 lbs. more than the lot than had been twice shorn. In addition the wethers once shorn, gained 2.7 lbs. more flesh than the other lot and it was made at a cheaper rate; for in the instance of the twice shorn wethers the cost of gain per 100 lbs. was $4.70; while the once shorn made 100 lbs. gain at a cost of $4.40. Considering these things, it did not pay to shear the wethers twice when the first shearing was done in December. It was thought that it might be advisable to shift the time of shearing towards the fall about one month with each trial, and in this way find out the time when it would be best to have the sheep shorn, if at all.

In the second experiment, which is the subject of this article, six wethers were divided into two lots. They were Shropshire grades of even fleece and form. The weight of each lot of three, when they were divided, was 289 lbs.

The experiment was started on November 4th, and the following day the wethers in Lot I were left unshorn, while those in Lot II were shorn. The wethers were kept under similar conditions, and they received like rations, consisting of cut corn fodder, rutabagas and oats. After seven weeks on such a ration, the grain feed was changed to a mixture of two parts oats and one part shelled corn by weight; and this was added to, after one week's feeding, by the addition of one part of oilmeal by weight. Both lots were given as much as they would eat of the grain and the other feeds mentioned.

Table summarizing the results of the experiment in shearing wethers before fattening them.

Principal data summarized.	Lot I. Three wethers once shorn.	Lot II. Three wethers twice shorn.	Differences in favor of Lot I.	Differences in favor of Lot II.
Weight Nov. 4th: wool and carcass	289 lbs	289 lbs	....	....
Weight Feb. 24th: wool and carcass	378 lbs	385 lbs	....	7 lbs
Gain in wool and flesh in 16 weeks	89 lbs	96 lbs	....	7 lbs
Average weekly gain per wether	1.8 lbs	2 lbs	....	2 lbs
Total quantity of wool shorn	19.5 lbs	23.3 lbs	....	3.8 lbs
Corn fodder eaten	591.75 lbs	726.25 lbs	134.5 lbs	....
Roots eaten	369 lbs	486 lbs	117 lbs	....
Grain eaten	234.5 lbs	254.25 lbs	19.75 lbs	....
Cost of food	$3.72	$4.27	55 cents	....
Cost of 100 lbs. gain	$4.17	$4.44	27 cents	....
Per cent. shrinkage of wool in scouring	34.2	20	....	14.2
Average length of fibre of fall shearing	....	2.9 ins	....	....
Average length of fibre of spring shearing	4⅛ ins	1.7 ins	....	....

In the preceding table the leading considerations of the experiment are summarized, so that it is easy to arrive at a general understanding of the results of the experiment. The detailed tables from which this summary is taken will be found in the appendix.

INFLUENCE ON THE WOOL.

In considering the influence of this practice on the wool growth, the leading matter that suggests itself is the way in which it effects the total quantity of wool clipped. When the wethers in Lot II were shorn on November 5th, they sheared a total of 14 lbs. At the second shearing, March 5th, they gave 9.3 lbs.; making a total clip of 23.3 lbs. unwashed wool. The wethers in Lot I, in the single shearing of March 5th, clipped 19.5 lbs.; thus leaving a balance in favor of the twice shorn sheep of 3.8 lbs. or an average of 1.2 lbs. more wool per head.

To indicate whether this larger weight was due to greater length of the fibre, the wool from the shoulder of each sheep was measured without disturbing the crimp. The average length of the fall shearing of the twice shorn sheep was 2.9 inches and the average length of the spring shearing was 1.7 inches. The average length of both clippings, considering the fibres of the fall and the spring shearings as of one length, was 4⅗ inches. The wool of the once shorn wethers was measured in a like way and the average length was 4⅓ inches, leaving an average difference in the total lengths of the two lots of ⅓ of an inch. This indicates an increased growth of the fibre in the instance of the twice shorn lot. If we do not measure the fibres of the fall and the spring shearings of the twice shorn lot as if they were the result of one shearing, then we find the average length of the fibres of both shearings of this lot to be 2⅓ inches, which compared with the 4⅓ inches that the fibres of the once shorn lot, measure shows them to be 2 inches shorter than the latter. As this effects the market value of the wool, it is proper to mention that the wool from twice shorn sheep would not bring so much per pound as

that from the once shorn, as the two shearings from the former leaves the wool much shorter in fibre. Instead of being graded as a combing wool, similar to the fleeces that were the outcome of a single shearing, the fleeces of the twice shorn sheep of Lot II would be classed as a clothing wool; and it would, on that account, bring about two cents less per pound in a critical market.

The quantity of grease or yolk in the wool has a marked influence on its weight. To determine this, samples were washed in water at a temperature of 100 Fahr. and soap was used. These samples were taken in the region of the shoulder of each sheep. The shrinkage of the fall and spring shearing of Lot 1 was determined by separate washings. The shrinkage of the fall shearing was found to be 20 per cent., and that of the spring shearing was also 20 per cent. The samples taken from Lot 11, treated in the same way, lost 34.2 per cent. By applying these facts, we find that Lot 1, shorn twice, clipped a total of 19.5 lbs. washed wool; while Lot 11, shorn once, sheared a total of 12.8 lbs. washed wool; a difference of 6.7 lbs. in favor of the twice shorn sheep.

INFLUENCE ON THE INCREASE OF FLESH.

There is a difficulty in determining the exact increase in flesh owing to the consideration that had to be given to the wool feature of the experiment. The difficulty is due to the fact that it is not possible to exactly determine what proportion of the increase is due to the growth of wool, and what is due to the increase of flesh. The best way to approximate the increase of flesh that has occurred to the writer is to assume that the average weight of the fleeces of both were similar at the beginning of the experiment; thus considering those that were not shorn until the spring to be the equal of the average of the fall shearing of the twice shorn sheep. In this way the weights of both lots, without their wool, would have been 275 lbs. at the beginning of the experiment. When the experiment was concluded the weights of the wethers, without their wool was as fol-

lows: the once shorn lot weighed 358.5 lbs., and the twice shorn weighed 361.7 lbs.; indicating the gain in flesh of those twice shorn to be 86.7 lbs., and that of the lot shorn once 83.5 lbs. This is a difference of 3.2 lbs. to the credit of the twice shorn sheep.

COST OF GAIN.

In those things which we have so far considered, the differences have been in the favor of the twice shorn lot; but the position changes when the cost of the gain is considered. It will be noticed that in all the items of the ration the lot containing the twice shorn sheep, consumed the most. The differences in the cost of gain are, however, very slight and do not quite counter-balance in money value the small amounts of wool and mutton that are to the credit of the twice shorn sheep. As may be seen in the summarized statement there is only a difference of 55 cents in the total cost of gain, and 27 cents in the cost of 100 lbs. gain to the credit of the once shorn sheep.

CONCLUDING STATEMENT.

The results from the experiments so far conducted are not extensive enough to permit of the deduction of decided conclusions; and the report of the foregoing experiment is only submitted as one of an unfinished series in which the wethers will be shorn in the different fall months. The experiment in which the wethers were first shorn in December was decidedly unfavorable to the practice; while that in which the twice shorn wethers were first shorn in November, affords evidence of some advantages connected with shearing twice that cannot be overlooked. At this time it may only be said that the differences originating between the results obtained by shearing on the foregoing dates, suggests the propriety of withholding an opinion until trials have been completed in shearing the sheep still earlier in the fall season.

FEEDING AND MARKETING LAMBS.

JOHN A. CRAIG.

AN EXPERIMENT RELATING TO THE METHODS OF FEEDING LAMBS AND THE TIME TO MARKET THEM.

The aim of this experiment was to gather information bearing on the practices followed in feeding lambs for market, and at the same time afford the means of forming an opinion as to the best time to market them.

In feeding the lambs the course most commonly pursued is to pasture them until fall and then fatten them during three or four months previous to marketing them. The generally accepted belief is that the lambs fed in this way grow larger and fatten more economically than those that are kept in a more thrifty condition by the feeding of grain. In the latter way of feeding the lambs are fed grain from the time they will first eat it until they are put on the market when from ten to twelve months old. As these methods differ radically, and yet are commonly practiced, it was thought advisable to investigate the subject until the differences between the practices would be apparent. The results herewith given have been obtained during the course of one complete trial.

This experiment extended from April 30th, 1891, to February 25th, 1892, and thus lasted 43 weeks. To make the application of the results clearer it will be well to divide the time of the experiment into the following periods:

First period: April 30th to July 9th: Before weaning.
Second period: July 9th to Nov. 19th: After weaning.
Third period: Nov. 19th to Feb. 25th: Fattening.

It was endeavored to carry the same lambs through all the periods, but it was found necessary to make some changes at the conclusions of the first and second periods. At the end of the first period the number of the lambs in each lot was increased from three to five, and at the end of the second period the number in each lot was reduced to four. These periods have been so divided for the additional reason that the lambs might have been marketed at the end of any period.

FIRST PERIOD.

(April 30th to July 9th.)

This period extends over the ten weeks that usually elapses before the lambs are weaned. The ewes and the lambs used in this experiment have been described in the report of last year in the reference therein made to feeding grain to lambs before weaning them. The six ewes and their six lambs at foot were high grade Shropshires. They were separated into two lots with three ewes and their three lambs in each. The ewes in both lots were given good pasture and their management in every particular was alike. In Lot 1 the lambs were given what they would eat of a mixture by weight of one part bran, 1 part cornmeal and ¼ part of oil meal. Those in the other lot, called Lot II (though referred to in the report of last year as Lot III) received nothing but good pasture during this period Placed in contrast the differences in the feeding of the lots is as follows:

Lot I, ewes pasture; lambs fed grain.

Lot II, ewes pasture; lambs no grain.

The lambs of Lot I were fed their grain by means of a lamb creep and they received it night and morning in the shed. The conduct of the ewes was so similar, as may be seen in the table given in the appendix, that the only matter to consider is the data relating to the lambs. Complete tables are given in the appendix and from them summaries have been made.

At the beginning of this period the lambs in the grain fed lot averaged in age about twenty days and those in the

other lot twenty-five days. As the period extends over ten weeks the lambs of both lots were about three months old when the end of the period was reached and the lambs weaned.

The following table is arranged so that the lots may be compared:

First period: Table comparing lambs fed grain with those that were not fed grain before weaning.

Data Summarized.	Lot I, lambs (3) fed grain.		Lot II, lambs (3) no grain.		Difference in favor of			
					Grain.		No grain.	
Weight at beginning April 30th.....	56	lbs	58	lbs	.. ..		2	lbs
Weight at ending July 9th..................	190.5	lbs	167.5	lbs	23	lbs		
Gain of three lambs in 10 weeks...	134.5	lbs	109.5	lbs	25	lbs		
Average weekly gain per lamb.............	4.48	lbs	3.60	lbs	.8	lbs		
Grain eaten	80	lbs	....		....		80	lbs
Cost of grain eaten.........................	56	cents	....		....		56	cents
Estimated market value at $9.36 per 100 lbs........	$17.27		$15.67		$2.05			

It is evident that it was profitable to feed the lambs of Lot I grain during this period, for they gained 25 pounds more than Lot II through the 80 pounds of grain mixture they received at a cost of 56 cents. In estimating the market value of these lambs at the end of the experiment the average of two years' prices on Chicago market has been used. Though these prices may to some appear high, yet in the statement of prices given elsewhere in this description it will be seen that they have been taken from actual sales of lambs approaching these weights. It is reasonable to infer that much of the benefit of grain feeding before weaning would be apparent in the second period, for the lambs so fed would be the most likely to do best during the time of weaning.

SECOND PERIOD.

(July 9th to November 19th.)

As this period began July 9th and continued until November 19th, an interval of 19 weeks, the lambs ranged in age from about three months at the beginning of it to nearly eight months on the conclusion. At the beginning of this period each lot was increased by the addition of two lambs making five lambs in each. The addition of the lambs mentioned was favorable to Lot II, as may be seen by a comparison of the total weights of the lots at the end of the first period with those of the same lot at the beginning of the second. The 21.5 lbs. that has been added to the weight of Lot II by the addition of these lambs has been allowed for in estimating the differences in the value of the lots at the end of this period and also on the conclusion of the third period. In the second period the relation of the lots remained the same; that is, those of Lot I received grain while those in Lot II were not fed grain. The grain mixture fed Lot I during this period consisted of ground corn and oil meal in the proportion of two of the former and one of the latter by weight. The table which follows presents the differences of the lots so that they may be readily compared.

Second Period: Table comparing lambs fed grain with those that were not fed grain before or after weaning.

DATA SUMMARIZED.	Lot I Lambs (5) fed grain.	Lot II Lambs (5) no grain.	Differences in favor of	
			Grain.	No grain.
Weight at beginning July 9	265 lbs	263.5 lbs	1.5 lbs	....
Weight at ending Nov. 19	518.5 lbs	413 lbs	105.5 lbs	....
Gain of 5 lambs in 19 weeks	253.5 lbs	149.5 lbs	104 lbs	....
Average weekly gain per lamb	2.06 lbs	1.57 lbs	1.09 lb	....
Grain eaten	915 lbs	....	....	915 lbs
Cost of grain	$7.38	....	....	$7.38
Estimated market value:				
Lot I 518.5 lbs. @$5.79 per 100 lbs	$30.02	....	....	....
Lot II 391.5 lbs. @$5.00 per 100 lbs	....	$19.57	$10.45	....

It may be noticed that the difference in the gain of the two lots of lambs is much more marked than it was during the first period. The weaning ordeal undoubtedly affected the lot that had no grain in a greater degree than it did the others. The lambs were all given excellent pasturage and yet during the week following the weaning those in the lot that did not receive any grain lost 5 lbs., while during the same week the grain-fed lot gained 10.5 lbs. At the end of this period, the differences in the appearance of the lambs were marked. The fleeces of the grain-fed lambs were smooth, dense and soft, while those of the lambs who had not received any grain were open, ragged and somewhat harsh. In the market value of the lambs there was at least three-fourths of a cent difference in favor of the grain-fed lambs per pound, and it is but their due to be credited with it.

The grain feeding appears, from the statement of gains given in the appendix, to have given the best results, during this period, in July and August. During these two months they gained 144.3 lbs., which is more than one-half of the gain that they made during the whole period. During the same months the other lot receiving no grain gained 70 lbs., which lacks only 9.5lbs. of being one-half of their gain during the entire period. The grain eaten by Lot 1 during these two months, amounted to 292 lbs., which is somewhat less than one-third of the total quantity they consumed during the period. In this way less than one-third of the total quantity of grain produced in these two months over one half of the total gain of the period. It will be understood from this that it gave the best results to feed grain during the two months that follow the weaning than it did later.

THIRD PERIOD.

(November 19th to February 25th.)

On November 19th, the lambs entered upon another period. This period extended from the foregoing date to the 25th of February, an interval of fourteen weeks. The same

lambs were in the lots as in the previous period with the exception that one lamb was dropped out of each lot.

During this period both lots were fed the same foods. The object was to determine the effect of the previous management of the lambs on their progress in fattening. The general belief has it that the lambs that are not fed grain up to this time will make a quicker and cheaper gain. As they were given similar food and conditions, the facts should go far to determine the truth or falsity of this belief. The lambs in this period received nearly the same quantities of corn fodder and roots with as much grain as they would eat. The grain mixture by weight consisted of two parts oats, one part corn, both unground, and one part oilmeal.

In estimating the market value of the lots at the end of this period it is necessary to consider whether the lambs are sold shorn or unshorn. As a rule it will be found the more profitable to shear lambs at this period before selling them. Pelt buyers gauge their prices somewhat on the wool, but the difference they make between a light and a heavy fleece is not sufficient to justify the sale of the lambs unshorn. It will be noted that in selling the lot unshorn Lot I does not get full credit for the extra amount of wool that they clipped. In answer to our inquiry Messrs. Clay Robinson & Co. of Chicago were kind enough to inform us that "when the sheep arrive in the spring the difference between the woolled and the shorn sheep is generally 75 cents to $1 per 100 lbs." The first mentioned estimate is employed in the following summary of the chief facts indicating the position of each lot:

Third Period: Table comparing lambs fed grain with those that were not fed grain previous to fattening:

DATA SUMMARIZED.	Lot I. Lambs (4) fed grain previously.	Lot II. Lambs (4) no grain previously.	Difference in favor of	
			Grain.	No grain.
Weight at beginning, Nov. 19	425.5 lbs.	337.5 lbs.	88 lbs.	....
Weight at ending, Feb. 25.	583.5 lbs.	503 lbs.	80 lbs.	....
Gain of 4 lambs in 14 weeks.	157.5 lbs.	165.5 lbs.	....	8 lbs.
Average weekly gain per lamb	2.8 lbs.	2 9 lbs.	....	.1 lb.
Grain eaten	534.75 lbs.	548 lbs.	13.25 lbs.	....
Corn fodder eaten	761.25 lbs.	688.75 lbs.	....	72.5 lbs.
Roots eaten	357 lbs.	357 lbs.	....	....
Cost of food eaten	$6.51	$6.48	....	3 cts.
Estimated market value:			....	....
If sold unshorn:				
Lot I, 583 lbs. @ $6.23	$36.32	....	....	....
Lot II, 481.5 lbs. @ $6.23	....	$29.99	$6.33	....
If sold shorn:				
Lot I, 542.6 lbs. @ $5.48=$29.73; " 40.4 lbs. wool @ 23c.=$9.29	$39.02	....	....	....
Lot II, 453.4 lbs. @ $5.48=$24.84; " 28.1 lbs. wool @ 23c.—$6.46	....	$31.30	$7.72	....

The results shown in the foregoing table make but a slight difference in the standing of the two lots. The lot that did not receive any grain previous to fattening made a greater gain of but 8 lbs., and the cost of the gain was only 3 cts. less than that of the other lot. As both lots were urged as rapidily as it was possible by forced feeding the difference in the progress seems small. It may be said that the previous feeding of the lambs had no effect on their progress in fattening during the third period. By the pre-figures it is shown that lambs receiving no grain up to the time of fattening cannot be expected to make any more gain than those that have been fed grain to keep them thrifty.

COMPARISON OF FINAL RESULTS.

Taking a general view of all the periods, we find that there are some striking differences in the lambs composing the lots. In reference to the condition of the lambs, it is only necessary to state that at the end of the first period there was but a slight difference in the weights of the two lots, yet at that time the grain fed lot would be worth more per pound than the other. At the end of the second period the difference was much more strikingly in favor of Lot 1; those that had grain given them. On the conclusion of the third period, the total weights varied in favor of the grain-fed lot, though the value of each lot per pound would be the same.

The lots differed most in the total quantity of wool that was shorn from each. The lot that was grain fed continually, sheared a total of 40.4 lbs., while those in the other lot sheared 28.1 lbs., or a difference of 12.3 lbs. There exists some doubt as to the degree to which it is possible to increase the wool product by forced feeding; in fact, some authorities are unfavorable to the belief. Previous to the time of fattening, these grain fed lambs were not heavily fed; the aim was to keep them in the thriftiest condition and not overforce them. In the division of the lambs into lots at the beginning of the experiment, the nature of their fleeces, as well as other qualities were considered; and the differences that are shown to have originated in the lots must have been brought about, to a great extent, by the variation in feeding.

The factors that contribute most to the weight of a fleece are its density, the amount of yolk it contains and the length of the fibres. Of the first mentioned merit we had ample evidence in the external appearance of the fleeces; and to test the presence of the other qualities the wool was scoured and measured. In scouring the wool the water was used at a constant temperature of 100 degrees Fahr., and soap was used, so that all the yolk or grease would be washed out. The samples consisting of one pound were taken from the shoulder of each sheep. Each pound was

washed separately and the per cent. of shrinkage has been determined from the losses of each of the fleeces in the respective lots. It was found that the wool of the grain fed lot lost in the scouring on an average 41.4 per cent., and that of the lot that did not receive grain before fattening lost 37.4 per cent.; a difference of 4 per cent. Applying this shrinkage, we find that Lot I yielded a total of 23.68 lbs. of washed wool and Lot II 17.8 lbs. It is evident from these figures that the increased weight of the fleeces of the grain fed sheep was due in a moderate degree to the greater amount of yolk it contained.

To assist still further in understanding the source of the increased weight of wool that was clipped from the grain fed lot, the length of the samples of wool taken from the shoulders of these sheep was measured without stretching, so that the crimp was not disturbed. The average length of the fibre of the lambs in Lot I was 5 inches and that of Lot II was 4.06 inches, or a difference of 3.76 inches in favor of the four lambs in Lot I. As the fleeces of the lambs were uniform in the character of the fibre aside from the length, this is a decided argument for good feeding.

THE RESULTS OF THE EXPERIMENT FROM A FINANCIAL STANDPOINT.

A general survey of the experiment offers a favorable opportunity for comparing the profits that may be derived from fattening lambs in the ways described, when placed on the market at the end of any of these periods. Under ordinary circumstances the three times of the year that lambs may best be marketed are July, November and March. Messrs. Clay, Robinson & Co., of Chicago, have kindly sent us a statement of some of their sales during these months in the course of the past two years, and from them we have arranged the table which follows. In requesting these figures it was intimated that it would be desirable to have data from such sales as were made of lambs that were about the same weights as those on the experiment. The statement is as follows :

Table showing average prices of lambs sold on Chicago market.

MONTH.	1891.			1892.			Average of two years.		
	Number of lambs.	Average weight.	Price per 100 lbs.	Number of lambs.	Average weight.	Price per 100 lbs.	Number of lambs.	Average weight.	Price per 100 lbs.
March	161	102½	$5.92	125	105	$6.55	286	103½	$6.23
July	184	66⅓	$10.11	140	72½	$8.62	321	69.4	$9 36
November....	104	92½	$5.62	65	98	$5.96	169	95.2	$5.79

From this it will be seen that during the month of July the lambs have been the highest of the year. Those sold in the spring months, particularly March, come next, and those of November are the lowest of all.

The subjoined statement has been prepared, based as far as possible on these prices. It was impracticable to determine the amounts of pasturage that the lambs of both lots ate. But as they had both the same, the lots may be compared with the understanding that the term "comparative cost" differs from the actual cost in that the former does not include the pasturage. The value of the lots at the end of the third period has been augmented by the value of the wool that was shorn. This was estimated to be worth 23 cents per pound. It should be stated that the cost of each lot has been brought up to the end of each period; and in case of the second and third period the average cost of the preceding periods has been included in the estimate.

Table comparing the market value and comparative value of the lots at the end of each period.

Market Value and Comparative Cost of Lots.	Lot I. Grain previous to fattening.		Lot II. No grain previous to fattening.		Difference in favor of.	
	Comparative cost.	Market value.	Comparative cost.	Market value.	Grain.	No grain.
End of 1st period; 3 lambs	56 c.	$17.72	......	$15 67	$1 49	
End of 2nd period; 5 lambs	$8.31	$30.02	....	$19.57	$2.14	
End of 3rd period; 4 lambs:						
If sold unshorn	$13.15	$36.32	$6.48	$29 99	....	41 cts.
If sold shorn	$13.15	$39.03	$6.48	$41.30	$1.05	

There may be more things to consider than those in the foregoing table before a right conclusion may be arrived at in regard to the differences in these lambs and the time to market them. It was noted that at the beginning of the second period Lot II, including the lambs that had not received any grain, had its weight increased by 21.5 pounds more than it was entitled to on account of the changes that were made in the number of lambs in the lots; this was considered in the foregoing estimate.

At the prices quoted it is indicated that lambs of the proper weights find a profitable sale in the month of July. Considering the costs, the labor of attendance and the increased risk of feeding the lambs throughout the year it would appear that July would be the best month for marketing the lambs, provided the circumstances are such as to be favorable for early lambs.

It is clear from the summary that has been given that it paid to feed the lambs grain through all the periods. The slight increase in the gain of Lot II may be overlooked as it is not sufficient to justifiy the assertion that the previous management produced it. The increased gain that the grain fed lot made before the fattening period remained to their credit to the end of the experiment.

SUMMARY OF RESULTS.

1. The three lambs that were grain fed before being weaned made 25 pounds more gain during the period of 10 weeks than those that were not fed grain. The grain fed lambs during that time ate 80 lbs of grain mixture, consisting of 1 part bran, 1 part cornmeal and ¼ part oilmeal, and costing in all 56 cents. At the end of the period an estimate of the comparative cost of the two lots and their market value shows that the three grain fed lambs in Lot I gave a profit of $1.49 more than those that had not received grain.

2. During the 19 weeks' interval after weaning and before fattening, the five lambs that were fed grain, gained 104 lbs. more than those that did not receive any grain. They ate 915 lbs of grain, consisting of 2 parts ground corn, 1 part oilmeal at a cost of $7.38; and this, added to by the cost of the previous period, makes the total cost to the end of the second period to be $8.31. At the end of this period an estimate of the comparative cost of the two lots shows that the five grain fed lambs in Lot I gave a profit of $2.14 more than those that had not received grain.

3. When both lots, those that had grain previously and those that had not, were fattened during the final period of 14 weeks, those that had not received grain previously gained 165.5 lbs. or 8 lbs. more than the other lot; and this gain was made at a cost of $6.48 or 3 cents less than the cost of those that had been given grain before this period. Thus nearly all the profitable gains that the grain fed lambs had made before and after weaning were yet to their credit at the end fattening period.

4. In the second period during the time extending from July 9th to September 3d, the grain fed lambs gained 144.3 lbs., which is over one-half the total gain of the period; while Lot II, without grain and on the same pasturage, gained less than one-half of their total gain in the same time. To produce this gain in the grain fed lot it took one-third of the total quantity of grain that they ate during the period. From this,

it is clear that it is specially advisable to feed grain to the lambs when they are being weaned.

5. The lambs in the lot that had been fed grain continuously sheared an average of 10.1 lbs. of wool per head, while those that did not get any grain until the fattening period, sheared 7 lbs. per head.

6. The fleeces of the grain fed lot contained more yolk; for when scoured the wool lost 41.4 per cent.; while that of the lambs that were not fed grain until the fattening period, lost 37.4 per cent.

7. The measurements of the wool taken from the shoulders of the lambs of both lots, show that the wool of the lot that had grain continuously, had grown the longer, for their fibers measured without disturbing the crimp, were 5 inches in length on an average; those of the other lot, measured in a like manner, averaged 3.7 inches.

CROSS BREEDING SHOPSHIRE AND MERINO SHEEP.

JOHN A. CRAIG.

The developments resulting from this work have more than a mere interest from a breeding standpoint. They have a useful bearing on the present condition of the sheep husbandry of this and other states. Since 1837, when the first sheep were brought into the state of Wisconsin until forty years later, the chief interest in the sheep farming of our state centered on its wool production. During that time flocks of exceptional merit were founded. In their establishment and future breeding a single eye was had to their wool bearing qualities. At that time there were slightly over one million such sheep in our state, and these included Saxony, Silesian, Rambouillet and American Merinos of the highest breeding. The sheep of the mutton breeds were not introduced until about 1845, and since that time there has been a rapid increase in their numbers. To indicate the extent of this the estimate of an authority* may be cited to the effect that in the year 1883 about 75 per cent. of the sheep of Wisconsin, or 1,020,000 out of 1,360,000 were of Merino breeding; the other 25 per cent. or 340,000 being of mutton sheep. It is further asserted that in 1890, the 1,618,000 sheep in the state included an equal number of both these classes. The chango in these statistics has been originated by the differences that the present markets make in the value of the wool and mutton products. The demand for wool has changed in its requirements and the price has not been such as to justify the breeding of sheep with a view to making a profit singly

* Special Report on the Sheep Breeding of the United States.

from their wool. A new market for mutton has grown and developed until it has become, even in this immature stage of its growth, a profitable one to supply. With these changes the consideration of our sheep breeders directed itself toward the question as to how the wool producing sheep could be best supplanted or moulded to satisfy the requirements of the modern market.

EXTENT OF THE INQUIRY.

The initial move in this work was made in 1888 when the Merino ewes were first bred; and the results of the cross have been apparent since 1889. The data, however, was scattered until 1891. In the spring of 1889 the Station flock included 36 Merino ewes. In the fall of that year twenty-six of the Merinos were bred to a Shropshire. From these twelve first cross ewe lambs were retained. In 1890 twelve Merinos were bred to a pure bred Shropshire ram, and in the fall of 1891 six other Merinos of the original flock were retained and bred. In 1892 the number of Merinos was reduced to three and these were bred to a Shropshire. These reductions in the number of the ewes have been made because of the need of room. It will be seen, however, that a considerable number of first crosses from the original source have been made.

In the fall of 1890 the first cross ewe lambs that had been dropped in the spring of 1889 were bred. Twelve were selected at this time as being of the desirable type. In the fall of 1891 these were not bred to a Shropshire. In 1892 six of the first cross ewes then about three and one-half years old and three of the first cross shearlings that were then about one and one-half years old were bred in the fall of that year.

Of the second crosses five dropped in 1891, and of these three are at present in the flock, and from them we now have young lambs that are of the third cross from the Merino. The limited number retained of all these crosses has been due in a large measure to the inability to provide room and range for them.

THE MERINO AS FOUNDATION STOCK.

It is apparent that whatever changes might be required in the direction of our sheep breeding operations, should be made with the Merino as a starting point. They are the common sheep of our state, having the additional advantage of being thoroughly acclimated; and it was readily supposed, aside from the matter of economy, that it would be advisable to use them as foundation stock. The Merino stands second to none in those attributes for which they have long been bred. Upon no other breed of sheep have so much skill and enterprise joined in the endeavor to produce and augment special qualities. As a sheep they have been subject to all climates and managements, and this has made them the most cosmopolitan of the sheep tribe. Activity, vigor and the ability to be almost self-sustaining are among their qualities. In addition, the Merino possesses a fleece that in the two qualities of fineness and density is hardly surpassed. On a mutton sheep the condition and quality of the fleece cannot be overlooked, but it is largely to the production of the most protective fleece that the breeders give consideration. These qualities, together with a number of minor ones, endorsed the selection of the Merino as foundation stock; while the condition of the sheep breeding interest of the state enforced it.

The Merinos that were used in this inquiry were reared in this state, and though not registered had been kept pure. They were representatives of the Merino so numerous in the west. They had been bred solely for their wool, so that there was a complete absence of any approach to a mutton type. The fiber of the wool was fine yet strong; and the fleece dense, even. The illustration that appears shows the form of a representative sheep used in this work.

The average weight of the 36 Merinos on May 18, 1889, when they had lambed, but before they had been shorn, was 73 lbs. On April 11, 1891, six of the best Merinos were weighed and the average weight then was 120 lbs. They were in lamb at this time and were unshorn. The latest

weight that we have is that of the three Merinos now in the flock, which were weighed February 7, 1893, and the average found to be 128 lbs.

The weights of the fleeces of the Merino ewes can only be given since 1891. They were shorn in the spring of that year during the interval from May 10th to 15th, and the average of the twelve then in the flock was 8.7 lbs. In 1892, when the fleeces had grown about one year, the average clip of the six ewes that were retained was 9.9 lbs. of unwashed wool. In 1893 when shorn the middle of April the average of the three ewes retained was 10.5 lbs.

These ewes had wool of excellent quality; they did not shear much, as the wool was not heavy in grease. As may be seen in the report of last year a fleece representative of those of the Merino ewes was washed and the shrinkage was found to be 34.5 lbs. The wool of the fleeces of these sheep was bright and soft. It was fine in fiber and though not long it may be said to be longer than is common on sheep of this description. The fleece was very dense and even over all the body without the slightest coarseness on the thighs or other parts.

THE SHROPSHIRE AS A CROSS.

The Shropshires have breed characteristics that justified their use in this work. They have been bred for a number of years past as a mutton sheep, and at the time this work was undertaken their wool was in demand and continues to be at the time of this writing. They had been under trial for some time in our state, and the climatic conditions that were common here seem to be suitable to their nature. The country being of about the same elevation and aspect as that of the "downs" of England, it was surmised that the sheep of this breed would satisfy our needs in this investigation.

The rams that have been used were registered sheep. They have been, in most instances, animals of considerable merit, but in no way may they be considered exceptional for this breed. The first ram used (the sire of the first cross ewe that appears in the illustration), was only of

ordinary merit. But more than this can be said of the ram that has been used during the past two years, and which is the sire of the second cross ewe lamb shown in the illustration. As may be seen from the illustration of this ram, he is thoroughly typical of the Shropshire breed.

THE FIRST CROSS.

In the report of last year the results obtained up to that time were noted so that it will not be necessary to more than briefly refer to these and add to them the additional data of the period that has elapsed since then. The first lambs of this cross were born in the spring of 1889. The first record of the weights of these crosses was made April 11th, 1891, at the same time that the Merinos were weighed, and it was found that the six first cross ewes averaged 140 lbs. each. They were then two years old and in moderate breeding condition. They were in lamb and unshorn. The latest weights were obtained February 7th, 1893, and the four ewes that were four years old at that time averaged 161.6 lbs., and the three two-year-old ewes averaged 145 lbs.

These weights are merely chronicled as matters of interest, for they tell nothing of the improvement in form and fleece that has resulted. In the illustration that accompanies this description the ewe that is there shown has been selected as of the best type of these sheep. The best of them are small sheep of smooth contour and as a rule symmetrical. They are of medium length and compactly built. The head in appearance approaches nearest to that of the Merino, being somewhat thick through the muzzle; and the face has much of the expression so peculiar to the Merino. The resemblance holds good in the pole, for this is higher than it is in the Shropshire. The ear seems to be similar to that of the Merino, as as it does not come so near the center of the pole, as in the Shropshire. The neck retains the attitude of the Merino and also has some of the loose skin characteristic of that breed. The shoulder lies close on the body, giving it smoothness, and there is no drop behind it. There is

much of the narrowness in front so strikingly seen in the ewe of Merino type. The brisket in the first cross stands out somewhat more from the body, making the form squarer from a side view. The body of the sheep shows marked improvement towards a mutton type from that of the Merino. The back is straighter and wider and the ribs more rounded though not deeper, and the loin is heavier fleshed. The hips of the typical first cross are smooth, not in the least ragged as is so with the Merino, while the rump is slightly longer and much smoother. In the twist there is a vast difference, the Merino being very light in the thigh and slack between the hind legs, where the first cross carries considerable flesh.

As evidences of inherent constitution it may be noted that the first crosses are invariably of large girth and the skin is of a very clear rose tint. As further evidence of this the fleece is surprisingly dense and even, there being no bareness observable in any region.

Of the changes that have been due to the cross none are more striking than those that the fleeces have undergone. The fleeces of the first cross decidedly surpasses that possessed by either of its ancestors. It is much better because of its evenness and its density. Though fleeces of the first crosses never were trimmed, yet they always had the appearance of being so treated. The evenness is carried all over the body with striking precision. In a fleece the matter of density is one of great importance, whether the point of view be that of the wool grower or that of the breeder of mutton sheep. The latter looks to it for he knows that the thrift of his sheep depends greatly on it; while the wool grower considers it a valuable merit for he realizes that it is a source of weight. It may be that the heaviest fleeced sheep are not those that make the most rapid progress in fattening, but it may be noted that those with dense fine fleeces are, as a rule, the sheep that make rapid and economical gains. This combination of density and evenness of fleeces is likely accountable for the fact that the first cross ewes were notably exempt from the snuffles.

FIG. 2.—Aged Merino ewe, No. 16; illustrating type of the Merino ewes that were bred to Shropshire rams.

FIG. 3.—Imported Shropshire ram, Shrawardine Swell, 7, A. S. A. 28271. Used in cross breeding experiment with Shropshire and Merino sheep.

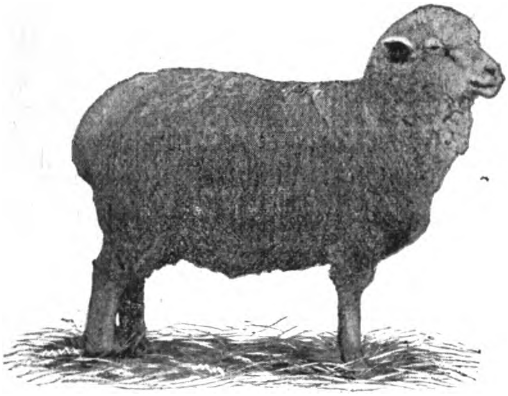


FIG. 4.—Four year old first cross Shropshire Merino ewe, No. 55; illustrating type resulting from crossing Shropshire ram on Merino ewes.

FIG. 5.—Two year old second cross Shropshire Merino ewe, No. 401; illustrating type resulting from crossing Shropshire ram on first cross Shropshire Merino ewes.

As to the quantity of wool shorn by the first crosses it may be stated that during the first fortnight of May, 1891, the twelve two-year-old ewes that were then in the flock were shorn and the averge weight of the fleeces was 8.9 lbs. This is slightly more than the average of the Merinos of the same year. A representative fleece of this shearing was washed and was found to shrink 33.3 per cent., which is slightly less than that of the Merino fleece treated in the same way. In the spring of 1892, from May 16th to the 25th, the six first cross three year old ewes sheared an average 10.1 lbs. Three first cross ewe lambs, at this time about two weeks over a year old, sheared an average of 9.4 lbs. In the spring of 1893 the five four year old first cross ewes then in the flock sheared 8.9 lbs. on an average, and the two ewes that were then two years old sheared an average of 9.7 lbs. From these weights it is evident that the differences in the fleeces of the Merinos and the first crosses are very slight.

In quality the wool of the first cross is slightly inferior to the Merino, and much superior to that of the Shropshire. It is finer, softer and purer than that of the Shropshire, while it is only inferior to the wool of the Merino in fineness.

In condition the first cross wool is bright and owing to the density of the fleece it keeps clean. The wool might be improved somewhat in respect to its strength, for it appears to have lost some of the elasticity and strength of fiber that is noticeable in the Merino wool.

THE SECOND CROSS.

It will be understood that this term is applied to the lambs that are out of first cross ewes and by a pure bred Shropshire ram. Those that are now in the flock were born in the spring of 1891. When weighed February 7, 1893, at the same time the first cross Merinos were last weighed, the three then in the flock averaged 132.3 lbs. The age of these sheep has to be considered in making a comparison with the others. While the second cross lambs were some-

what uniform in appearance, yet they showed slightly more variation in form and fleece than could be found among first crosses.

In regard to the weights of the fleeces when shorn for the first time the third week in May, 1892, the four then in the flock averaged 8.2 lbs.; while three of the same shorn this spring, 1893, in the second week of April, sheared 7 lbs. of unwashed wool. The fleeces are somewhat lighter than those of the first cross at a corresponding age.

The wool of the second cross ewes is longer than either that of the Merino or the first cross but it is not equal to them in density or evenness. It is inferior in fineness, softness and purity but in these respects it is superior to typical Shropshire wool. It is a bright, strong and long wool that would bring a high price in present markets.

As to the appearance of the best type of the second cross the accompanying illustration will indicate it clearly. In contrasting the form of these sheep it is to be borne in mind that the Merino is aged, the first cross a four year old and the second cross only two year old. The others have reached their full development, while the second cross is yet young.

In critically examining the appearance of the second cross it is evident that the Shropshire type is closely approached. In form the sheep of this cross are long and possessed of the rotundity of form that is a Shropshire characteristic. The head in shape, thickness of muzzle. and expression of the face retains an inkling of the Merino ancestry, while the darker face comes from the extra infusion of Down blood. There is a general fullness of the forequarter that does not appear in the first cross. The body sinks deeper between the fore legs and the latter stand farther apart. The shoulder is better fleshed, the back broader and the ribs spring out still better than in the first cross. The thigh is fleshed much better toward the hocks. A marked improvement has been made over the first cross particularly in the plumpness of the thigh and fullness between the hind legs. There appears to be no evidence of a decrease in constitution.

In regard to the general appearance of the second cross it would be a hard matter for a novice to distinguish between the best of them and pure bred Shropshires. It is fair to remind the reader that there were some that did not show much more of the Shropshire features than the first cross. Another cross will bring these up to those of the more advanced type.

As the third crosses are the lambs of this year it would be attempting too great a forecast to place an estimate on them based on their present appearance. They do not, however, show many of the loose folds of skin that have been observable in the lambs of the first cross at their ages. It seems that they will be very similar to the second cross in type and fleece. We have, however, sufficient data from the previous crosses to believe that they point the way to those who wish to supplant their Merino flocks with sheep of mutton qualities.

ON THE ECONOMY OF SILOING INDIAN CORN "EARS AND ALL."

F. W. WOLL.

From many sources it has been maintained during late years that the practice of siloing corn "ears and all", is a waste of food material; it is said that the ears do not add any more food value to the silage, when this is fed in connection with other food stuffs, than would an equal quantity of fodder corn; in other words, that silage from corn with the ears picked off will go as far as silage from corn with ears on it. The main objection to the system of siloing corn "ears and all" is that it takes away the ear corn on the farm. It has been stated that $1,000,000 is thus wasted annually in this state alone by this practice, and the matter has given rise to a good deal of discussion in the agricultural press.

During the summer of 1891, this Station planned to investigate the question of the economy of the two kinds of silage, and especially their value as food for milch cows. To this end part of the corn crop of 1891 was set aside for the experiment. In September 1891, the wooden silo at the university farm was divided in the middle from north to south by a partition made up of two thicknesses of inch boards; the two halves were again divided from east to west by a single thickness of boards placed somewhat nearer one wall than the other. The four pits thus formed received corn as follows: Pits No. I and III, corn run through feed cutter with ears on. Pits No. II and IV, corn, the ears of which were removed previous to the cutting of the corn and the filling of it into the silo. The corn siloed was the Pride of the North variety (a yellow dent corn); the ears were re-

moved from the corn in every other two rows of the field, and were kept separately; the corn was cut in inch lengths for the silo. When six rows of each kind of corn had been filled into the silos, a thin layer of hay was placed on the top, so as to enable us to distinguish between each layer of corn from six rows, and thus make it possible to feed out the two kinds of silage from the same part of the field at the same time.

The corn was cut for the silos at the time the kernels were denting.

The silos were filled September 10–14, 1891; the two first silos were opened December 16, 1891, and the other two February 1, 1892. When the top layer of six to twelve inches of spoilt silage was cleared off, the silage was of very good quality, aromatic and perfectly sweet. The weights of corn filled into the silos were as follows:

	Silo I. (Ears.)	Silo II. (No ears.)	Silo III. (Ears.)	Silo IV. (No ears.)
	Lbs.	Lbs.	Lbs.	Lbs.
Filled into silo........	29623	20394	39198	24152
Taken out, good silage.....	25358	16693	31382	18491
Taken out, spoilt silage....	1035	1239	2259	1921

The losses were considerable, owing to the small size of the silos. This was especially the case with silos III and IV, which were not opened until late in the winter. The total quantity of corn siloed was 113,367 lbs. and of silage taken out 90,955 lbs., a loss of nearly 20 per cent. The losses of dry matter were 15.8 per cent. in case of the silage with ears (silos I and III) and 24.2 per cent. in case of the silage with no ears in it (silos II and IV).

The ear corn was dried in the field until September 22, and was then transferred to a large room in Agricultural Hall where it was spread out over the whole floor and so left until December 15th.

Weight of ear corn September 22, 12,987 lbs.; December 15, 11,016 lbs.; loss 1,971 lbs., equal to 15.2 per cent.

The ear corn was then transferred to a corn crib, the corn corresponding to the different layers in the silos being placed in different compartments of the crib. Weight of corn as fed out during and after the experiment 10,511 lbs., loss since September 22, equal to 19.1 per cent.

The following quantities of the two kinds of silage and of ear corn was secured in all from equal areas of land.

Silage with ears in it	56159 lbs.
Silage without ears	34496 lbs.
Dried ear corn	10511 lbs.

If we calculate the dry matter obtained in case of the two methods of preserving the corn crop we find that in siloing the corn ears and all we obtained 19,950 lbs. of dry matter in the silage with ears in it; 9,484 lbs. in the silage without ears, and 9,122 lbs. in the dried ear corn, or 18,606 lbs of dry matter in the silage without ears and the ear corn put together. This means a loss of nearly 7 per cent. which was suffered by handling the corn crop separately instead of putting it into the silo "ears and all."

FEEDING EXPERIMENT WITH MILCH COWS.

In order to ascertain the feeding value of the silage with ears in it compared with the silage without ears and the dried ear corn, it was decided to feed the silage from pits I and III against the silage from pits II and IV in addition to the corresponding dried ear corn.

Sixteen cows of our herd were selected for the experiment; half the number received silage with ears in it during the first period of the experiment and the other half received silage without ears, plus the corresponding dried ear corn in such quantities as the different cows could utilize. During the second period the feed was reversed. In addition all cows received a fundamental ration of oats, shorts and hay, as is shown by the following schedule:

RATION I.		RATION II.	
Ground oats	3 lbs. per day.	Ground oats	3 lbs.
Shorts	2 lbs. per day.	Shorts	2 lbs.
Hay	4 lbs. per day.	Hay	4 lbs.
Corn silage, with ears in it, ad libitum.		Corn silage without ears, Dried ear corn	ad libitum.

The method of preparing the two kinds of silage and the ear corn fed in the experiment has already been described.

The hay was mixed timothy and blue grass. The oats were grown in the vicinity of Madison. The shorts were bought from our local roller mills.

COWS ON THE EXPERIMENT.

The following is a list of the cows on the experiment with information as to their breed, age, time of calving, and average live weight:

Cows on the experiment.

Name.	Breed.	Age	Date of calving.	Served.	Approximate live weight.
Mattie	Grade Holstein	10 yrs.	Oct. 22, '91	..	1060 lbs.
Emma	Grade Jersey	10 yrs.	Dec. 3, '91	Dec. 27, '91	760 lbs.
Palmera	Grade Jersey	3 yrs.	Oct. 15, '91	Jan. 28, '92	780 lbs.
Rosette	High Grade Jersey	4 yrs.	Sept. 15, '91	Jan. 19, '92	840 lbs.
Daisy 2nd	High Grade Jersey	6 yrs.	Sept. 22, '91	Dec. 21, '91	840 lbs.
Rue	Registered Jersey	8 yrs.	Nov. 17, '91	Dec. 30, '91	900 lbs.
Daisy	Grade Jersey	10 yrs.	Nov. 26, '91	Dec. 18, '91	740 lbs.
Bessine	High Grade Jersey	6 yrs.	Jan. 10, '92	Feb. 6, '92	760 lbs.
Beauty	Native	11 yrs.	Nov. 2, '91		1100 lbs.
Bunn	Holstein-Jersey	8 yrs.	Sept. 10, '91	Dec. 18, '91	1130 lbs.
Gay	Grade Jersey	9 yrs.	Sept. 29, '91	Dec. 1, '91	830 lbs.
Galena	High Grade Jersey	8 yrs.	Sept. 11, '91	Dec. 5, '91	930 lbs.
Sylvia	Grade Jersey	10 yrs.	Sept. 25, '91		860 lbs.
Bessie 2nd	High Grade Jersey	6 yrs.	Sept. 13, '91	Dec. 13, '91	820 lbs.
Sylvan	High Grade Jersey	4 yrs.	Oct. 25, '91	Dec 25, '91	670 lbs.
Bryant	High Grade Jersey	6 yrs.	Dec. 31, '91	Jan. 23, '92	810 lbs.

The first eight cows received silage with ears in it during period I, and the second lot received silage without ears and ear corn during period I of the experiment.

The two cows Bessine and Bryant had not calved at the time when the experiment began, and they were therefore not put on the experiment until the last week of period I, 21 and 32 days from calving, respectively. They were fed the feed which they were to receive on the experiment for a week previous to this time.

The preliminary feeding to the experiment began December 14; the experiment proper began December 28, 1891, and lasted until March 28, 1892. First period lasted seven weeks and second period six weeks. Owing to the fact that the silage in silo IV was nearly all fed out on March 28, the experiment was discontinued at that time, instead of on April 4, as originally planned. The two periods were separated by an intermediate week when no account was taken of the feed eaten or the milk product except that the latter was weighed every day, as is the case in our herd the year around.

CONDUCT OF THE EXPERIMENT.

The cows were fed twice a day and watered once a day, in the forenoon. The feed eaten by the cows was carefully weighed out, the silage being fed ad libitum and each cow given according to her appetite at each meal; the amount of dry corn given each cow varied from four to six pounds a day, according to the capacity of each animal. The corn was fed in the ear with husks on during the first two weeks of both periods; as a large quantity of corn passed through undigested (see page 70) the ears were ground, cob and all, during the other weeks except on some few days when it had to be fed whole, on account of the wind power not being available. Half the grain feed and hay was fed in the morning and half at night. The feed boxes were cleaned every morning and any feed that might have been left uneaten, weighed back.

The cows were milked at 5 a. m. and 4:30 p. m., the milking being always done by the same farm hand and in the same order. The fat content of the milk produced by each cow was determined by Babcock's test in the morning and evening milk separately, during the first, fourth and seventh week of period I and during the first, third and sixth week of period II.

The cows were weighed daily in the forenoon during the weeks when the milk was analyzed, and the water drank by each animal was also weighed at the same time.

SAMPLING OF FODDERS.

The silage fed was sampled every week of the experiment and other feed stuffs every week when milk analyses were made. A quart jar full of the coarse feeds was taken for a sample, and a pint jar full of the concentrated feed stuffs. In all 80 samples of fodder were taken and analyzed for moisture and protein preparatory to or on the experiment proper; 1,344 determinations of the fat content of milk produced were made, besides a very large number of weighings in connection with the food and the products. In the following pages only average figures for weeks or periods for each cow are given so as not to take up too much space. In some cases only averages for the whole lots of cows are given, when it was thought that more detailed data would be of no special interest to the reader.

LIVE WEIGHT AND WATER DRANK.

The following table gives the average data for the live weight and water drank by each cow during both periods; each figure is the mean of eighteen weighings:

Average live weight and water drank, in pounds.

Name of cow.	SILOED CORN. Period I.		DRY EAR CORN. Period II.		Name of cow	SILOED CORN Period II.		DRY EAR CORN Period I.	
	Live weight.	Water drank.	Live weight.	Water drank.		Live wght.	water drnk	Live wght.	water drnk
Mattie.........	1061	53.3	1093	48.1	Beauty......	1074	61.1	1091	70.7
Emma........	759	53.7	765	47.4	Bunn	1185	59.4	1152	65.1
Palmera......	780	54.3	795	46.8	Gay.........	863	40.1	847	41.5
Routh	835	43.3	875	40.7	Galbia......	956	53.0	941	60.7
Daisy 2nd......	835	56.8	878	50.6	Sylvia	837	40.4	343	50.6
Rue............	896	50.3	918	47.5	Bessie 2nd..	836	53.2	819	66.6
Daisy.........	738	59.4	728	55.6	Sylvan.....	707	45.7	684	47.9
Bessine........	756	57.3	750	51.4	Bryant......	805	41.1	805	55.6
Average.....	833	53.6	850	48.5		909	49.3	898	57.3
Average for all cows....	870.5	51.4	874.0	52.9					

The first eight cows gained 17 lbs. on an average when the feed was changed from silage with ears in it to silage without ears dried corn, and the other lot gained 11 lbs. when the fodder was changed the other way. All but four cows weighed more during the second period than during the first. If we compare the first set of weighings with the last set we notice that all but the same four cows weighed more during the last week of the experiment than at the beginning of the same; the average weight for sixteen cows are as follows:

Average live weight Dec. 21-28, 1891	858 lbs.
Average live weight Mar. 21-28, 1892	881 lbs.

or the cows gained on an average 23 lbs. during the experiment.

All the cows drank less water during the second than the first period of the experiment; the first lot going from siloed corn to dried corn thus drank 5.1 lbs. less on the average, and the second lot whose feed changed in the opposite direction drank 8.0 lbs. less. Comparing the average for all cows we find that the cows drank 1½ lbs. less water per day and weighed 3.5 lbs. less while on silage with ears in it than while on the other ration.

FODDER EATEN.

The following quantities of silage were eaten during the experiment by the sixteen cows:

Ration I.	Total.	Av. feed per day per cow.	Containing dry matter.
Corn silage with ears	33720 lbs.	49.1 lbs.	17.34 lbs.
Hay	2630 lbs.	3.8 lbs.	3.25 lbs.
Oats	2058 lbs.	3.0 lbs.	2.59 lbs.
Shorts	1372 lbs.	2.0 lbs.	1.75 lbs.
Total	....	....	24.93 lbs.
Ration II.			
Corn silage without ears	27571 lbs.	40.2 lbs.	11.05 lbs.
Ear corn	4141 lbs.	6.0 lbs.	5.21 lbs.
Hay	2641 lbs.	3.8 lbs.	3.25 lbs.
Oats	2058 lbs.	3.0 lbs.	2.59 lbs.
Shorts	1372 lbs.	2.0 lbs.	1.75 lbs.
Total	....	....	23.85 lbs.

We notice that the cows ate nearly 17 tons of silage with ears in it, and nearly 14 tons of silage with ears picked off plus 2 tons of ear corn, in addition to the fundamental ration. We shall presently see what the returns were from food eaten. The quantity of dry matter consumed per day per head was 24.93 lbs. (siloed corn), against 23.85 lbs. (dried corn). As in previous experiments we find also in this case that cows eat more when on the ration containing the larger quantity of succulent fodder (see page 54, 8th Annual Report of this Station).

QUANTITY OF MILK PRODUCED.

The total quantities of milk produced by each cow during the experiment with the total feed eaten will be found in the following table:

Food eaten and milk prodcued, in pounds.

Names of cows.	Silage With Ears in It.			Silage With Ears in It.					Milk Yield.
	Silage.	Milk yield.	Hay refused.	Silage.	Ear Corn	Cobs refused.	Corn and cob me'l refusd	Hay refused.	
	Period I—7 weeks.			Period II—6 weeks.					
Mattie.......	2842.1	1189.6	4.0	2184.9	336.0	18.8	.....	......	895.9
Emma.......	2118.7	954.6	......	1875.4	245.0	16.2	.....	......	596.3
Palmera	2229.1	764.5	7.5	1488.1	242.9	8.3	9.0	15.0	549.8
Rosette.. ..	1876.7	397.7	4.5	1277.7	245.0	15.2	6.5	3.8	309.9
Daisy 2nd...	2620.5	921.4	2.0	1939.4	335.0	13.8	2.3	6.8	762.3
Rue.........	2152.1	683.9	16.0	1584.5	246.1	11.7	.....	21.5	491.5
Daisy........	2358.4	1064.0	15.5	1601.0	245.0	12.5	.....	24.4	789.5
Bessine*. ...	300.0	164.0	......	1660 6	245.0	17.3	.....	......	864.4
Total.....	16492.6	6139.7	49.5	13061.6	2140.0	108.8	17.8	71.4	5259.6
	Period II—6 weeks.			Period I—7 weeks.					
Beauty......	2780.2	941.5	......	2381.4	398.2	5.5	.....	. ....	1188.3
Bunn........	2759.3	892.8	7.8	2570.4	406.2	10.0	.....	3.5	1124.9
Gay.........	1731.9	502 2	23.8	1792.2	186.5	12.8	.....	19.0	627.6
Galena......	2208.9	776.3	4.0	2103.8	318.3	7.8	.....	6.0	915.9
Sylvia.......	2125.5	699.7	6.5	1931.7	318.3	12.5	.....	1.5	808.4
Bessie 2nd...	2156.7	670.0	.....	1877.1	318.3	10.0	.....	1.0	797.1
Sylvan......	1705.9	333.7	5.5	1629.9	211 8	12.5	.....	1.0	547.4
Bryant*.....	1808.5	879.0	16.8	222.8	43.8	3.3	.....	.. ...	154.1
Total.......	17226.9	5695.2	64.4	14509.3	2201.4	74.4	.....	32.0	6163.7
Total for 16 cows.....	33719.5	11834.9	113.9	27570.9	4341.4	183.2	17.8	103.4	11423.3
Average per per cow ..	49.1	17.25	.2	40.2	6.3	.3	.....	.2	16.65

*Only one week during first period.

The difference in milk yield amounts to 411.6 lbs. in favor of silage with ears in it; this is a gain of 3.6 per cent.

PRODUCTION OF MILK AND BUTTER FAT DURING SIX WEEKS.

If the analyses of milk are tabulated and the production of fat per cow calculated on the basis of the data obtained, we shall be able to ascertain the influence of the feed in this direction. Below are given the quantities of silage and total dry matter consumed by the cows during the weeks when the analyses of the milk were made, and also the milk yield, the percentage of fat and the yield of fat during these weeks.

Total quantities of food eaten and of milk and butter fat produced when fed silage with ears in it, in pounds.

Name of cow.	Silage eaten.	Dry matter eaten.	Total milk yield.	Average per cent. fat. A. M.	Average per cent. fat. P. M.	Total yield of fat.
PERIOD I, WEEKS 1, 4 AND 7.						
Mattie	1221.8	600.8	507.6	2.99	2.87	14.91
Emma	896.6	485.7	408.2	4.49	4.37	18.03
Palmera	950.3	503.3	325 7	5.11	5.26	16.89
Rosette	797.8	449.6	168.1	5.25	5.15	8.51
Daisy 2nd	1125.1	568 1	404.4	5.11	4.99	20.44
Rue	901.8	482.5	287.1	5.66	5.43	15.94
Daisy	984.3	521.5	447.4	4.89	4.98	22.07
Bessine *	300 0	162.3	164.0	5.09	5.06	8.32
Total	7177.7	3773.8	2712.5	....	....	125.11
Average per cow per day	*46.6*	*24.50*	*17.61*	*4.82*	*4 76*	*.81*
PERIOD II, WEEKS 1, 3 AND 6.						
Beauty	1374.6	636.9	469.5	4.14	3.95	19.02
Bunn	1384.3	639.7	443.2	3.01	2.88	13.08
Gay	873.6	457.0	245.7	4.45	4.19	10.62
Galena	1107.4	544.1	390.7	5.54	4.61	19.99
Sylvia	1074.9	532.0	344.7	5.62	5.17	18.66
Bessie 2nd	1093.9	539.4	335.4	5.99	5.47	19.27
Sylvan	869.3	461.9	169.6	6.71	5.39	10.37
Bryant	904.0	461.3	436.0	4.53	4.50	19.65
Total	8682.0	4272.3	2834 8	....	......	130.66
Average per cow per day	*51.7*	*25.43*	*16.87*	*4.99*	*4.52*	*.78*
Average for all cows	*49.3*	*24.99*	*17.29*	*4.91*	*4.64*	*.80*

* Only one week included.

During the second period the first eight cows in the above table received silage with no ears in it, and dry ear corn, and the last eight cows received this kind of silage during the first period. The food eaten by the cows while on silage without ears and dry ear corn, with the product of milk and butter fat are given in the following table:

Total quantities of food eaten and of milk and butter fat produced while fed silage without ears and dry ear corn, in pounds.

NAME OF COW.	Silage Eaten.	Ear Corn Eaten.	Dry Matter Eaten.	Total Milk Yield.	Av. per cent. Fat. A. M.	Av. per cent. Fat. P. M.	Yield of Fat.
	PERIOD II, WEEKS 1, 3 AND 6.						
Mattie	1067.8	168.0	594.5	440.8	2.99	2.89	12.95
Emma	680.6	122.0	447.9	295.6	4.75	4.52	13.69
Palmera	752.3	121.0	465.3	278.7	5.32	5.15	14 56
Rosette	614.8	122.0	436.3	152.3	5.61	5.44	8.30
Daisy 2d	970.3	168.0	564.5	377.0	5.19	5.27	19.68
Rue	801.6	122.0	477.7	240.8	5.65	5.59	13.50
Daisy	810.9	122 0	477.8	391.7	4.86	4.76	18.82
Bessine	815.0	122 0	492.3	433.7	5.08	4.73	21.28
Total	6573.3	1067.0	3956.3	2610.1			122.78
Av. per cow per day	***39.1***	***6.4***	***25.69***	***16.95***	***4.93***	***4.79***	***.73***
	PERIOD I, WEEKS 1, 4 AND 7.						
Beauty	1033.1	159.2	586.2	508.4	3.54	3.59	18.13
Dunn	1094.3	159.2	600.8	484.2	2.87	2.78	13.66
Gay	764.6	82.5	447.4	265.7	4.28	4.11	11.16
Galena	909.8	132 3	527.7	387.9	4.80	4.18	17.50
Sylvia	823.3	132.3	500.1	344.5	5.26	5.02	17.74
Bessie 2d	788 0	132.3	592.1	334.6	5.40	5.15	17.72
Sylvan	679.6	87.8	420.9	229.6	6.19	5.71	13.71
Bryant*	222 8	43.8	151.4	154.1	4.39	4.54	6.87
Total	6315.5	885.9	3826.7	2709.0			116.49
Av. per cow per day	***41.0***	***5.8***	***22.77***	***16.13***	***4.59***	***4.38***	***.76***
Average for all cows	***40.0***	***6.1***	***24.17***	***16.52***	***4.76***	***4.59***	***.74***

* Only one week included.

255.77 lbs. of fat was produced while the cows were on the siloed corn ration against 239.27 lbs. while on the dry ear corn ration; difference 16.5 lbs. or 6.9 per cent. in favor of the siloed corn ration. The difference in the milk yield during the same weeks was 125.8 lbs. or 4 per cent. in favor of the siloed corn ration.

Summarizing the result of the feeding experiment we have briefly:

33750 lbs. of silage, with ears in it, fed in addition to hay and grain feed (the feed containing 17127.5 lbs dry matter in all) produced *11,835* lbs. of milk.

27571 lbs of silage, with ears picked off, plus 4341 lbs. of dry ear corn, in addition to hay and grain feed as before (the feed containing 16491.7 lbs. of dry matter in all), produced *11,423* lbs. of milk.

For the six weeks in which the milk was analyzed, we have the following data:

1560 lbs of silage with ears in it in addition to hay and grain feed (the feed containing 8046.1 lbs. dry matter in all), produced *5547.3* lbs. of milk containing *255 8* lbs of fat.

12889 lbs. of silage, with ears picked off, plus 1953 lbs. of dry ear corn, in addition to hay and grain feed as before (the feed containing 7783 lbs. dry matter in all) produced *5,319.1* lbs. of milk, containing *293.3* lbs of fat.

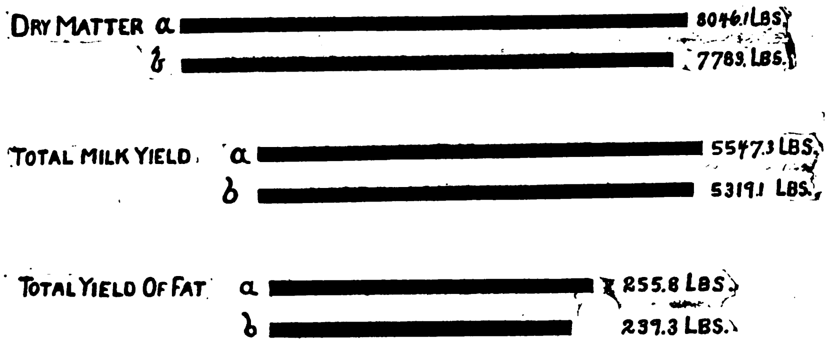


FIG. 6.—a, Siloed Corn. b, Dry ear corn.

Considering the feed consumed and the product during the whole experiment, we notice that the cows ate 6,149 lbs. more of silage with ears in it than of the other kind, but in the latter case they ate 4,341 lbs. of dry ear corn and produced 412 lbs. less of milk. The silage with ears in it therefore was unquestionably the more economical.

Considering the six weeks during which milk analyses were

made, we find that 2,971 lbs. more of silage with ears in it was eaten than of the other kind, but in return 1,953 lbs. of ear corn were consumed with the latter, and the product fell short of 228.2 lbs. of milk and 16.5 of fat.

RELATION BETWEEN YIELD AND DRY MATTER EATEN.

When we take into account the dry matter in the food consumed in either case, we are able to compare the two rations directly with one another.

First, considering the whole experiment we find that the cows consumed in all 17,127.5 lbs. of dry matter when on the siloed corn ration and 16,491.17bs. when on dry corn ration, or 100 parts of dry matter produced 69.1 lbs. of milk in one case and 69.26 lbs. of milk in the other case.

Second, considering the six weeks when the milk was analyzed we have that the cows ate 8,046.1 lbs. of dry matter while on siloed corn ration and 7,783.0 lbs. while on dried corn ration, or,

100 parts of dry matter produced—

In siloed corn ration	.68.9 lbs of milk and 3.15 lbs of fat
In dry corn ration	.68.3 lbs of milk and 3.08 lbs of fat
Difference in favor of siloed corn	.6 lbs of milk and .10 lbs of fat
Or in per cent	.9 per cent and 3.2 per cent.

While the dry matter in the dried corn ration proved slightly more effective as far as milk production is concerned, when the returns from the whole experiment are considered, the reverse is true, the six weeks of the experiment being considered when milk analyses were made. In either case the differences are very small, however, and no opinion as to the greater efficacy as to milk production of the dry matter in the one or the other ration can be pronounced on basis of them. In case of the fat produced during part of the experiment the siloed corn ration is the more effective, as a three per cent. better yield of the fat was secured from the same quantity of food material in case of the siloed corn ration than with the dried corn ration. While the data that go to make up these results are very numerous and obtained from sixteen animals fed during three months it would not do to generalize from this single experiment.

It is plain, however, that the difference in the efficacy of the food materials in the two rations is not in favor of those of the dried corn ration.

DIFFERENCE IN PRODUCTIVE CAPACITY OF COWS.

To show the difference in the productive capacity of different animals we give below the quantities of milk and butter fat produced from a hundred parts of dry matter consumed by each animal on the experiment during the two periods. It will be remembered that the first eight cows received siloed corn during the first period of the experiment and the last eight cows received dry corn during the same period.

Produced by 100 pounds of dry matter in food, in pounds.

Name of cows.	Days from calving at beginning of expr't.	Silage with ears in it.		Silage without ears.	
		Milk.	Butter fat.	Milk.	Butt'r fat
Mattie	60	84.5	2.5	74.2	2.2
Emma	13	84.0	3.7	65.9	3.1
Palmera	68	64.7	3.35	59.9	3.1
Rosette	97	37.4	1.9	34 9	1.9
Daisy 2nd	90	71.2	3.6	66.8	3.5
Rue	34	69.5	3.3	50.3	2.8
Daisy	25	85.8	4.2	81.9	3.9
Bessine	21	101.0	5.1	88.1	4.3
Average per cow	*51*	*73.5*	*3.46*	*65.3*	*3.1*
Beauty	49	78.7	3.0	86.7	3.1
Bunn	102	69.3	2.0	80.6	2.6
Gay	83	53.8	2.3	59.4	2.5
Galena	101	71.8	3.7	73.5	3.3
Sylvia	87	64.8	3 5	68 9	3.5
Bessie M	99	62.2	3.6	56.5	3.0
Sylvan	57	36.7	2.2	54.5	3.3
Bryant	32	94.6	4.3	101.1	4.5
Average per cow	*78*	*65.9*	*3.1*	*72.7*	*3.2*
Average for all cows	*64*	*69.7*	*2.27*	*69.0*	*3.16*
Highest returns	....	101.0	5.2	101.1	4.5
Lowest returns	....	37.4	1.9	34.9	1.9

We notice that while one cow gave 101.1 lbs. of milk and 5.2 lbs. of fat for every 100 lbs. of dry matter she ate in her food, another cow did not produce more than 34.9 lbs. and 1.9 lbs. of milk and butter fat respectively from the same quantity of food materials, or she produced only 34 per cent. as much milk and 36 per cent. as much fat as the other cow. The latter would therefore yield nearly as much as three cows of the former type, and would only eat the food required for one of them.

The average figures for all cows given in the table are not exactly the same as those given on p. 65 for the reason that the latter were calculated from the relation between the total food eaten and the total product, while the figures in the above table give the average returns from each single cow; the ratio of food to product being different in case of the different cows, the average figures found by the two methods cannot be exactly the same, but the differences are slight and of no consequence.

The chart showing the average daily milk yield of the cows during the experiment is prepared on basis of the data from the fourteen cows that were on the experiment from the beginning; the same applies to the chart showing the average decrease in the daily milk yield. It will be noticed that the siloed corn ration produced a higher daily milk yield, as we have already seen, and also that it seems to keep up the yield of milk as well as the other ration. The dotted line in the large chart (Fig. 7) indicates the change in the milk yield throughout the experiment without regard to the feed, it being prepared from the average data for both rations.

I have been unable to explain satisfactorily the sudden increase in the yield of milk during the second week of period II, Feb. 22–29. The temperature was higher during this week, as will be seen from the following average figures; mean daily temperature February 7–15, 16.4°, February 15–22, 19.1°, February 22 to 29, 31.3°, February 29 to March 7, 27.8° F. The weather was rainy and damp during the week, as it rained five days out of the seven; total rain fall .92 inches; furthermore as there was less wind than during

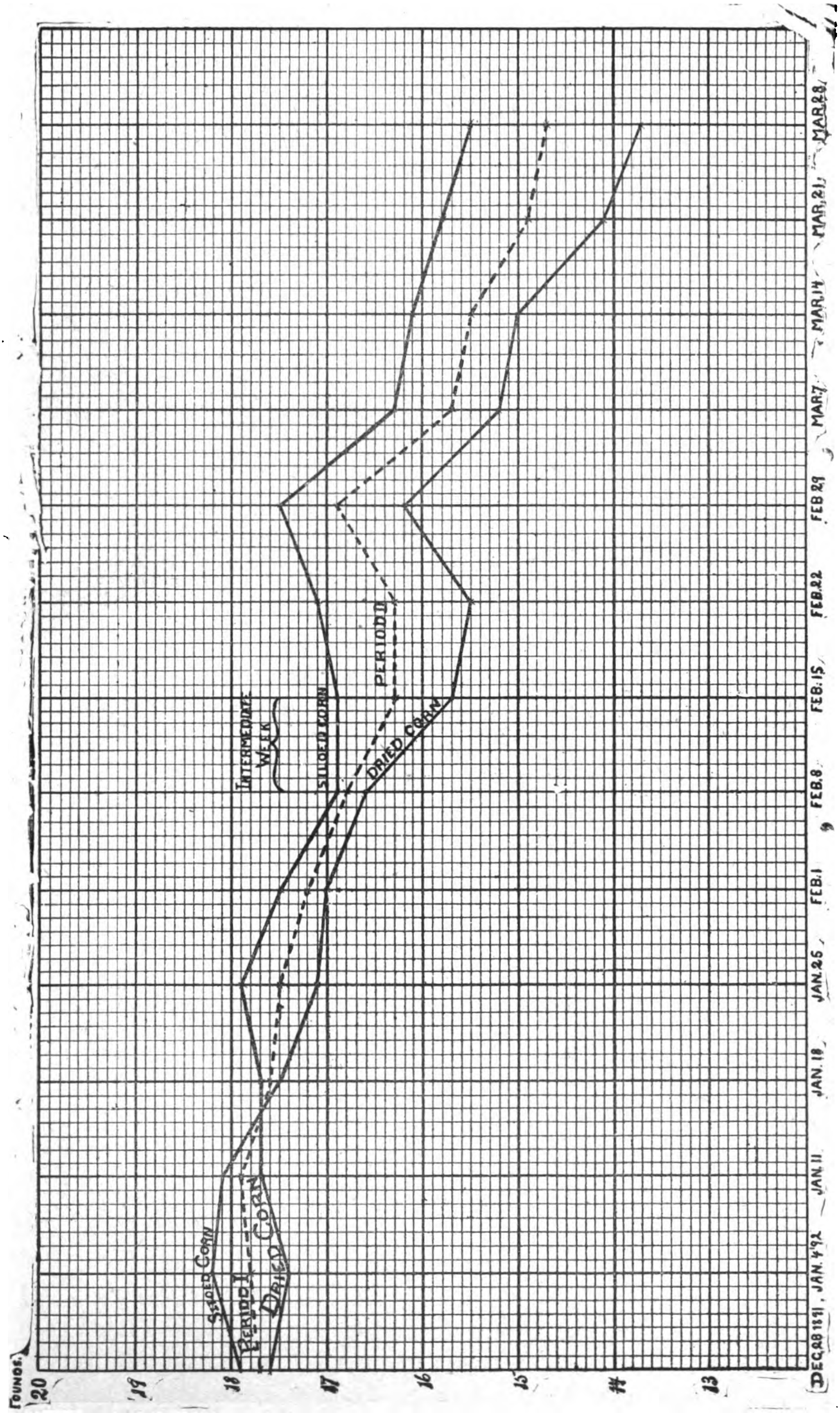


FIG. 7.—Average daily milk yield in pounds.

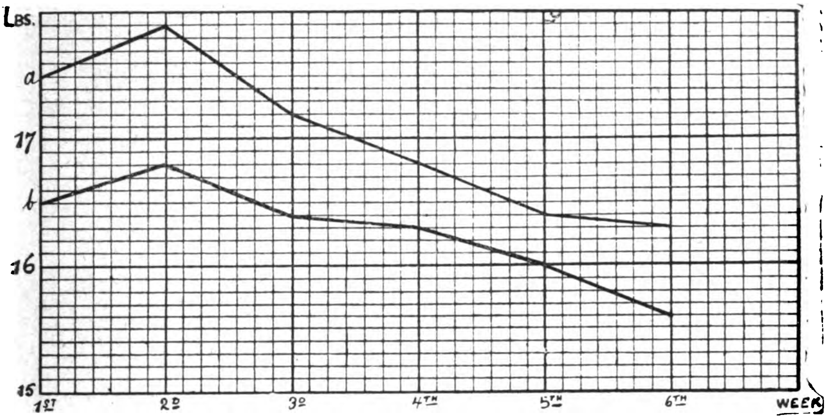


FIG 8.—Average decrease in daily milk yield.

the preceding week, the ventilation in the stable certainly must have been less perfect. All the cows but one gave more milk during the second week of period II than during the first week, the highest increase being 13.9 lbs. for the whole week, or nearly 2 lbs. a day (Mattie) and the average for all sixteen cows, half a pound a day.

WASTE IN FEEDING WHOLE EAR CORN TO MILCH COWS.

It was stated that each cow on the experiment received dried ear corn according to her capacity. We found during the preliminary feeding that the cows could not eat on an average more than 6½ lbs a day; the larger cows were therefore fed 7 to 8 lbs and the smaller 3 to 4 lbs. a day. Even with this quantity fed, the manure showed a large amount of whole kernels of corn, and a majority of the cows left the cobs untouched. To ascertain the quantity of corn wasted through incomplete mastication the dung from the two cows, Bunn and Mattie, the two heartiest eaters on the experiment, was carefully saved for 24 hours, February 25–26. The dung was weighed and the kernels of corn separated as far as practicable by washing the manure with large quantities of water. Mattie was fed dry corn and Bunn siloed corn.

	Mattie.	Bunn.
Weight of dung for 24 hours	84¾ lbs	74 lbs
Undigested kernels of corn, about	1¼ qts	1 pt
Weight of kernels	1.05 lbs	.367 lbs.
Calculated on ear corn in the ration fed	*18 3* per ct	*3.0* per ct.

Nearly one fifth of the dry corn went through whole in case of this one cow, while the cow that was fed siloed corn wasted 3 per cent. The germination of the whole corn collected was tested in a Geneva apparatus; 42.9 per cent. of the whole corn from Mattie's dung sprouted; the sixty kernels on the germination test were all seemingly unbruised; nearly one half of the kernels collected from the dung were more or less cracked. None of the kernels in the siloed corn germinated.

Owing to the large loss of corn passing through the cows fed whole corn, this was ground, husks and all, after the second week of both periods. Even by this manner of feeding, small pieces of corn were occasionably noticeable in the dung from some of the cows, and it was therefore evident that we could not advantageously have fed more ear corn to the cows on the experiment.

FINANCIAL ASPECT OF THE QUESTION.

We have seen in the preceeding that 17 tons of silage from corn siloed "ear and all," fed to sixteen cows produced somewhat better results than 14 tons of silage with no corn in it and more than 2 tons of dry ear corn, both kinds of silage having been supplemented by the same quantities of hay and grain feed. The product of milk was 411.6 lbs. larger and of butter fat 16.5 lbs. larger during six weeks of the experiment. The corn siloed ears and all was filled directly into the silo after having been run through the feed cutter. In case of the other kind of silage the stalks and leaves of the corn were treated in the same way. In addition comes the expense of picking off the

ears, the care of the ear corn until it was dry enough to be placed in the corn crib, and finally, the grinding of ears and husks previous to feeding them to cattle.

It is evident that the farmer siloing his corn "ears and all' has the advantage of it, as besides procuring the feed at less expense, he will get at least as much out of his corn when it is put into the silo as when it is dried and fed separately. While the work of siloing the corn with ears in it was two-fifths more than that of siloing the stalks and leaves (see page 55), in the latter case the expense of picking off the ears and taking care of the corn afterwards must be added to the cost.

WHICH SYSTEM TO ADOPT.

We believe that the cheapest and most convenient way to preserve the whole corn crop is to fill it directly into the silo. On every farm enough ear corn ought to be picked off to supply seed corn and to furnish feed for swine and other farm animals who do not take very well to silage, and the stalks and leaves may be filled into the silo on the top of the corn siloed "ears and all." In this way the bulk of the corn may be siloed at the proper time when the corn is in the roasting stage, and the corn plot which is to furnish ear corn may be left in the field until the corn is fully matured. If preferred the corn stalks from this smaller plot may be field-cured and fed dry instead of siloed.

For milch cows the siloing of corn "ears and all", according to the teachings of this experiment, is the more economical and convenient way of handling the corn crop.

RATIONS FOR DAIRY COWS.

F. W. WOLL.

In the spring of 1892 a circular letter was addressed to a number of dairymen and breeders in the state, asking for information in regard to the rations fed to their cattle during the preceding winter. The object in view was to obtain some definite knowledge of what may be advantageously fed to milch cows under the conditions present in our state to produce the best results. This bulletin contains extracts from the replies obtained, the rations fed, with their component parts and such discussions as the results suggested. Sixteen dairymen furnished one or more complete rations as fed in their herds during last season, making the number of rations obtained twenty-one in all. Among those furnishing data are some of the leading Wisconsin dairymen and breeders, and it is believed that we are able to present here many rations which may be considered model according to our conditions.

The ration fed is given in each case; also its cost according to average Wisconsin prices, the annual yield per cow of butter or milk in each herd, and other information which seemed of value; the quantities of digestible components in each ration calculated per thousand pounds live weight are further given, so that the rations may be compared with one another. The reader who is unfamiliar with the method of calculation of the nutrients in a ration, is referred to the chapter on Composition of Feeding Stuffs, at the end of this Report, where the subject is discussed at some length. The table given in this chapter formed the basis for the calculations.

The following market prices formed the foundation for the calculations of the cost of each ration; the prices for feeding stuffs will vary somewhat with the different localities and seasons, but the figures given are considered average prices; they may easily be changed to suit the particular case of any one farmer.

Average Wisconsin Prices for Feeding Stuffs.

	Per ton.	1 lb costs cts.
Corn silage	$ 2.00	.1
Clover silage	2.00	.1
Clover hay	8.00	.4
Timothy hay	8.00	.4
Mixed hay	8.00	.4
Marsh hay	4.00	.2
Fodder corn	4.00	.2
Corn stalks	3.00	.15
Cotton seed meal	28.00	1.4
Oil meal, O. P.	25.00	1.25
Malt sprouts	14.00	.7
Wheat bran	13.00	.65
Wheat middlings	14.00	.7
Corn meal	16.00	.8
Corn and cob meal	15.00	.75
Oats	18.00	.9
Barley straw	4.00	.2
Oat straw	4.00	.2

RATIONS FED BY SIXTEEN WISCONSIN DAIRYMEN.

I.—Richland Center, Richland Co.

"Sixty cows in the herd; Durham and Red Polls; average weight of cows 1,200 lbs.; average yield of milk 6,000 lbs.; of butter 260 lbs.; milk contains from 3.6 to 4.0 per cent. fat; cows go dry two months. Specialty in farming, butter production."

RATION.—Hay 5 to 8 lbs.; corn silage 30 lbs.; oil meal 3 lbs.; ground corn with cob and oats, equal weight, mixed, 10 lbs.

Cost of ration per day 17.7 cts.

Components of ration.—The following table represents the quantities of the nutrients in this ration calculated for cows of 1,000 lbs. live weight. Average quantity of hay is taken as 6½ lbs.

	Organic matter.	Digestible.			Total digestible matter.	Nutritive ratio.
		Protein.	Carbohydrates.	Fat.		
5.4 lbs hay	4.29	.19	2.31	.05	2.55	....
25.0 lbs. corn silage	6.08	.28	3.30	.18	3.76	... .
2.5 lbs oil meal	2.13	.68	.81	.18	1.67	....
4.2 lbs. corn and cob meal	3.50	.27	2.36	.12	2.75	....
4.2 lbs. oats	3.60	.38	1.88	.17	2.43	....
Total	19.61	1.80	10.66	.70	13.16	1:6.9

II.—Ft. Atkinson, Jefferson Co.

"Twenty-seven cows in the herd; grade Jerseys; average weight 900 lbs.; average yield per year of milk 5,500 lbs., of butter 320 lbs.; average fat in milk 5.25 per cent.; most of the cows go dry six to eight weeks in July and August; a few are persistent milkers who are not dried up at all. Specialty in farming, butter production."

RATION.—Well eared corn silage 27 lbs.; dry fodder corn with some ears on 8 lbs.; clover hay 6 lbs.; what little oat straw they would eat, perhaps 1 or 2 lbs.; oat meal 4 lbs.; wheat bran 4 lbs.

"In all each cow was fed about 14 lbs. of grain feed, as there were about 6 lbs. of corn in the silage and corn fodder."

Cost of ration 14.6 cents.

Components of ration.—In the same way as before we find that the above ration calculated for cows of 1,000 lbs. live weight would contain:

Total organic matter	27.37 lbs.
Digestible protein	1.98 lbs.
Digestible carbohydrates	14.36 lbs.
Digestible fat	.76 lbs.
Total digestible matter	17.10 lbs.

Nutritive ratio 1:8.1.

III.—Same herd as preceding; fed after March 1st.

RATION.—Silage 40 lbs.; dry fodder corn 4 lbs.; wheat bran 8 lbs.; hay and straw as in No. 2.

Cost per day 12.7 cts.

Nutrients in the ration.

Total organic matter	27.80 lbs.
Digestible protein	2.19 lbs.
Digestible carbohydrates	14.54 lbs.
Digestible fat	.74 lbs.
Total digestible matter	17.47 lbs.

Nutritve ratio 1:7.4.

"The cows did a little better on this ration. I fed about the same last year with the exception that a part of the time I fed two lbs. oil meal in place of same amount of oats, which was a slight improvement we thought."

IV.—Rosendale, Fond du Lac Co.

"Seventeen cows in herd, twelve Guernseys, two Guernsey grades, and three Short Horn grades. Average weight of cows, 1,050 lbs.; annual yield of milk per cow 6,143 lbs.; average per cent. of fat 5.0; cows generally go dry about two months during July and August. Specialty in farming, breeding and butter production."

RATIONS.—Corn silage, 40 lbs.; clover hay, 5 or 6 lbs.; roller bran 10 lbs.; old process oil meal, 2 lbs.

Cost of ration 15.2 cents.

Nutrients in ration.

Total organic matter	22.64 lbs.
Digestible protein	2.46 lbs.
Digestible carbohydrates	11.26 lbs.
Digestible fat	.76 lbs.
Total digestible matter	14.48 lbs.

Nutritive ratio, 1:5.3.

"This is a heavier grain ration than before, but shall feed as much hereafter, perhaps substituting gluten meal for oil meal."

V.—Rosendale, Fond du Lac Co.

"Fifteen to twenty cows in the herd; registered Holstein-Friesians; average weight 1,200 lbs.; milk yield from 6,000 to 16,000 lbs.; average per cent. fat in milk 3.5; cows go dry generally during summer months. Specialty in farming, breeding and the production of the most and best quality of milk we can get."

RATION.—Silage, 50 lbs.; hay, 10 lbs.; bran and oats equal parts by measure, 10 lbs.; oil meal, 2 lbs.

Cost of ration, 19.4 cts. per day.

Nutrients in the ration:

Total organic matter	25.18 lbs.
Digestible protein	2.11 lbs.
Digestible carbohydrates	13.58 lbs.
Digestible fat	.79 lbs.
Total digestible matter	16.48 lbs.

Nutritive ratio, 1:7.3.

"We calculate to feed all the cows will eat and clean up good. The ration given is a good stiff ration and a good working ration and don't think on an average our herd will eat more and eat it clean day after day. Some will eat more and some less, and we had two large cows refuse this ration this winter. Were we to change this ration would increase the grain feed

and lessen the hay. And were we to make it to suit ourselves exactly would reduce silage and hay a little and add carrots or beets and increase grain feed a little, but it is hard, back-aching work to grow the roots. A manager of a dairy herd must know his cows, know what they can stand and do good work, and such a man will seldom find two cows in the same herd of the same turn or capacity."

VI.—Darien, Walworth Co.

Thirty cows in the herd; Holstein-Friesians; average weight, 1,200 lbs.; yield per cow of milk, 7,000 lbs.; of butter, 300 lbs.; average per cent. of fat in milk for year, 3.95. Cows go dry for nearly two months and come in at all times. Specialty in farming, butter production and breeding.

RATION.—Silage with very litt e corn, 50 lbs.; clover and timothy hay mixed, 10 lbs. or less; corn meal, 3 lbs.; bran or middlings, 3 lbs.; linseed meal, 1 lb.

"When we have plenty of good clover hay we substitute it for the timothy, and oats for bran or middlings."

Cost of ration, 14.6 cts.

Nutrients in the ration:

Total organic matter	27.12 lbs.
Digestible protein	1.79 lbs.
Digestible carbohydrates	12.49 lbs.
Digestible fat	.70 lbs.
Total digestible matter	14.98 lbs.

Nutritive ratio, 1:7.8.

VII.—Palmyra, Jefferson Co.

Sixteen cows in the herd; weight 500 to 900 lbs.; average weight, 800 lbs. (assumed); cows go dry about a month previous to calving.

RATION (fed during November and December, 1891)—**Silage, 35 lbs.; hay, 4 to 6 lbs.; malt sprouts, 4 lbs.; bran, 2½ lbs.; cotton seed meal, 1½ lbs.**

Cost of ration, 11.9 cts. per day.

The ration contained:

Total organic matter	22.79 lbs.
Digestible protein	2.75 lbs.
Digestible carbohydrates	11.85 lbs.
Digestible fat	.77 lbs.
Total digestible matter	15.37 lbs.

Nutritive ratio, 1:4.9.

VIII.—From same herd; fed during January, 1892.

RATION.—Silage, 35 lbs.; clover hay, 3 lbs.; marsh hay, 2 lbs.; malt sprouts, 4½ lbs.; bran, 2½ lbs.; cotton seed meal, 1½ lbs.; cob meal, 4½ lbs., also skim milk and butter milk.

Cost of ration per day, 15.4 cts., not considering the skim milk or butter milk fed.

Nutrients in the ration:

Total organic matter	28.97 lbs.
Digestible protein	3.43 lbs.
Digestible carbohydrates	15.41 lbs.
Digestible fat	.97 lbs.
Total digestible matter	19.81 lbs.

Nutritive ratio, 1:5.1.

IX.—From same herd; fed during February, 1892.

RATION.—Silage, 35 lbs.; mixed hay, 6 lbs.; malt sprouts, 5 lbs.; oil meal, 2½ lbs.; bran, 5 lbs.; cob meal, 3½ lbs.; skim milk.

Cost per day, 18.4 cts.

Total organic matter	31.77 lbs.
Digestible protein	3.92 lbs.
Digestible carbohydrates	17.47 lbs.
Digestible fat	1.03 lbs.
Total digestible matter	22.42 lbs.

Nutritive ratio, 1:5.0.

X.—From same herd; fed during March, 1892.

RATION.—Silage, 25 lbs.; clover hay, 6 lbs.; cotton seed meal, 1½ lbs.; malt sprouts, 3½ lbs.; bran, 4 lbs; corn meal, 4 lbs.

Cost of ration, 15.3 cts.

Total organic matter	28.46 lbs.
Digestible protein	3.47 lbs
Digestible carbohydrates	14.84 lbs.
Digestible fat	1.05 lbs.
Total digestible matter	19.36 lbs.

Nutritive ratio, 1:4.9.

Comparing the last four rations, the farmer says that no better results were obtained when 5 lbs. of malt sprouts were given than when 3 to 3½ lbs. were fed. This is probably because all of the rations contained more protein than was necessary for supplying the wants of the system for nitrogeneous nutrients, and the profitable limit was most likely reached already in case of the first ration.

XI.—Whitewater, Walworth Co.

Twenty nine cows in the herd; 22 Jersey grades, 7 natives. Average weight 900 lbs. "During the winter the cows in milk have averaged a pound of fat each, daily: 4.50 to 4.75 per cent. fat in the milk; cows go dry about two months in July and August. Might improve the ration by feeding more oil meal, but do not know that it would pay better." Specialty in farming, butter production.

RATION.- Cut sheaf oats, 6 lbs.; corn silage, 30 lbs.; bran, 4 lbs.; oil meal, 2 lbs.; mixed meadow hay, 10 to 12 lbs.

Cost of ration, 15.1 cts.

The ration contained--

Total organic matter	28.96 lbs.
Digestible protein	2.22 lbs.
Digestible carbohydrates	15 12 lbs.
Digestible fat	.76 lbs.
Total digestible matter	18.10 lbs.

Nutritive ratio, 1:7.6.

XII.—Whitewater, Walworth Co.

Twenty-five cows in the herd; Jerseys, about half the herd two-year old heifers. Milk per cow per year, 4,183 lbs.; butter, 224 lbs.; cows go dry about one month in the fall. Speciılty in farming, breeding.

RATION.—Clover hay, 12½ lbs.; prairie hay, 12½ lbs.; silage, 40 lbs.; bran, 10 lbs.

Cost of ration, 20.5 cts.

The ration contains about the following quantities of nutrients.*

Total organic matter	35.78 lbs.
Digestible protein	3.00 lbs.
Digestible carbohydrates	18.83 lbs.
Digestible fat	.86 lbs.
Total digestible matter	22.69 lbs.

Nutritive ratio, 1:6.9.

This is an unusually heavy ration, and it seems reasonable to suspect that the amounts of hay eaten are overestimated, as young, light cows could hardly consume such quantities as those given, in addition to 40 lbs. of silage and a liberal grain feed, unless they were extremely rich milkers. Same applies to the following ration as well.

XIII.—From same herd; ration to be fed during the present winter.

RATION.—Clover hay 12½ lbs.; prairie hay, 12½ lbs.; corn silage, 20 lbs.; ground corn, 7½ lbs.; oats, 7½ lbs.

Cost of ration, 24.8 cts.

Components of the ration:

Total organic matter	36.66 lbs.
Digestible matter	2.71 lbs.
Digestible carbohydrates	20.11 lbs.
Digestible fat	1.08 lbs.
Total digestible matter	23.90 lbs.

Nutritive ratio, 1:8.3.

"My reasons for changing from bran to ground corn and oats are that I can raise and grind the latter myself, as we have our own engine and feed mill and I think the dairy farmer should always, if practical, raise his own feed."

*General average for corn silage adopted in the calculation.

XIV.—Oconomowoc, Waukesha Co,

Forty-five cows in the herd; Jerseys and grade Jerseys; average weight 800 lbs. (estimated); average yield of milk per cow, 4,000 lbs.; average per cent. of fat in milk, 5 per cent. Cows go dry about one month, some during each month of the year.

RATION.—Corn silage, 40 to 50 lbs.; clover hay, about 5 lbs.; wheat bran, 8 lbs.; oil meal, 2 lbs.

"This is about my average ration for the past two years; very satisfactory except as to high price of bran." Specialty in farming: cream for city consumption.

Cost of ration, 14.2 cts.

Nutrients in ration:

Total organic matter	29.00 lbs.
Digestible protein	2.97 lbs.
Digestible carbohydrates	14.83 lbs.
Digestible fat	.96 lbs.
Total digestible matter	18.76 lbs.

Nutritive ratio, 1:5.7.

XV.—Viroqua, Vernon Co.

Thirty-one cows in the herd; grade Jerseys; average weight, 800 lbs.; average per cent. of fat in milk, 4.17; most of the cows go dry in June to August. Specialty in farming, production of milk and butter.

RATION.—Corn silage, rich in ears, 50 to 70 lbs.; timothy, or mammoth clover, 6 to 8 lbs.; a bundle of sheaf oats (equivalent to oat straw, 6 lbs., and threshed oats, 3 lbs); oil meal, 3 lbs.

Cost of ration (taking average quantities), 16.5 cts.

*Nutrients in the ration.**

Total organic matter	34.81 lbs.
Digestible protein	2.64 lbs.
Digestible carbohydrates	18.82 lbs.
Digestible fat	1.03 lbs.
Total digestible matter	22.49 lbs.

Nutritive ratio, 1:8.0.

"The feed is changed every few days; while eating so much silage the cows were crazy for straw and were fed considerable. Keep young stock in good condition on a bushel of silage and plenty of oat straw daily; fed more silage than ever last winter and cows have done the best they ever did. Instead of oil meal only, would use oil meal, corn meal, bran and so on."

XVI.—New Holstein, Calumet Co.

Eight cows in the herd; Short Horns; average weight of cows, 1,150 lbs.; average yield of butter, 175 lbs. (estimated). Cows go dry six to

*General average for corn silage adopted in the calculation.

eight weeks during the latter part of summer. Specialty in farming, production of beef and butter.

RATION.--**Cut straw, 10 lbs. (mostly barley straw); timothy hay, 15 lbs.; whole straw, 4 to 5 lbs.; bran, 4 lbs.; oat meal, 3 lbs.; oil meal, 5 lbs.**

Cost of ration, 14.8 cts.

Total organic matter	26.29 lbs.
Digestible protein	1.33 lbs.
Digestible carbohydrates	13.50 lbs.
Digestible fat	.46 lbs.
Total digestible matter	15.29 lbs.

Nutritive ratio, 1:10.9.

XVII.—Brodhead, Green Co.

Twenty-eight cows in the herd; Jerseys; average weight 925 lbs. (estimmated): yield of butter per year, 350 lbs.; cows go dry three to six weeks at all times in the year.

RATION.—Corn Silage, 30 lbs.; cut corn stalks, 12 to 14 lbs. (all they will eat reasonably clean); 10 lbs., one-half by measure of wheat bran and one-half of corn and oats ground together, (one part corn by measure, two parts oats), with a sprinkling of pease.

Cost of ration, 13.9 cts.

Assuming the cows received about a pound of pease per day, the above ration will contain about the following quantities of organic and digestible matter.

Total organic matter	25.85 lbs.
Digestible protein	1.80 lbs.
Digestible carbohydrates	14.70 lbs.
Digestible fat	.75 lbs.
Total digestible matter	17.25 lbs.

Nutritive ratio, 1:9.1.

XVIII.—Lake Geneva, Walworth Co.

Thirty cows in the herd; Guernseys; average weight, 1,150 lbs.; average annual yield of milk per cow, 7,000 lbs.; of butter, about 400 lbs.; average per cent. of fat in milk, 5.11.

"Most of the cows go dry in August, but some come in at different seasons. Specialty in farming, butter production."

RATION.—Corn silage, 32 lbs.; clover silage, 22 lbs.; clover and timothy hay mixed, 5 lbs.; bran, 6 lbs.; ground oats, 4 lbs.; cotton seed meal, 3 lbs.

Cost of daily ration, 19.1 cts.

Components of ration.

Total organic matter	24.50 lbs.
Digestible protein	2.87 lbs.
Digestible carbohydrates	11.56 lbs.
Digestible fat	.96 lbs.
Total digestible matter	15.39 lbs.

Nutritive ratio, 1:4.8.

XIX.—Colgate, Waukesha Co.

Seven cows in the herd; Jerseys and natives; average weight, 950 lbs.; average yield per cow of milk, 4,500 lbs.; of butter, 210 lbs. "Cows come in at all times of the year and are dry not more than two months. Some milk from calf to calf; nearly all will, and I shall probably let them hereafter. Four of my cows came in at two years of age and were with their first calves last winter. Specialty in farming, breeding and production of butter."

RATION.—Clover hay, 5 lbs; fodder corn, 16 lbs.; ground oats 2⅝ lbs.; bran 5½ lbs.

Cost of ration, 11 cts.

Components of ration:

Total organic matter	22.47 lbs.
Digestible protein	1.75 lbs.
Digestible carbohydrates	12.06 lbs.
Digestible fat	.57 lbs.
Total digestible matter	14.38 lbs.

Nutritive ratio, 1:7.6.

"I shall feed more oats and bran and from 1 to 2 lbs. of oil meal next winter. Also pea meal to some extent."

XX.—Lake Mills, Jefferson Co.

Forty-nine cows in the herd: registered and grade Holsteins. Average live weight of cows, 1,200 lbs. (assumed).

RATION.—Corn silage, 25 lbs.; cut stover, 20 lbs.; marsh hay, 10 lbs.; ground oil cake, 3 lbs.; wheat middlings, 3 lbs.

Cost of ration, 13.4 cents.

Components of ration:

Total organic matter	25.29 lbs.
Digestible protein	1.77 lbs.
Digestible carbohydrates	13.54 lbs.
Digestible fat	.61 lbs.
Total digestible matter	15.92 lbs.

Nutritive ratio, 1:8.4.

XXI.—Sparta, Monroe Co.

"Twenty-five head in the herd; registered Jerseys; average livo weight, 1000 lbs.; products sold as milk, cream and butter; total cash receipt for same last year, $84.43 per head; this does not include anything for skim milk or butter milk. Cows go dry six weeks in July and August."

RATION.—Corn silage, 35 lbs.; what hay they will eat up clean, about 11 lbs.; hay, clover and timothy, principally clover; 8 lbs. of a mixture of 5 parts of wheat bran, 3 parts ground oats, and 1 part oil cake meal (old process) mixed by volume.

Cost of ration. 15.1 cts.

Assuming that 8 lbs. of clover hay and 3 lbs. of timothy hay were fed; we find that the ration contained about the following quantities of nutrients:

Organic matter	24.00 lbs.
Digestible protein	2.28 lbs.
Digestible carbohydrates	11.99 lbs.
Digestible fat	.78 lbs.
Total digestible matter	15.05 lbs.

Nutritive ratio, 1:6.0.

"The ration would be improved by doubling the amount of oil meal; last year I fed twice as much oil meal, and the average per cent. butter fat was about one half per cent. more than this year from the same cows, which I attribute to oil meal, other conditions being equal. Breeding, prime business, making butter second; if I was feeding for milk only I would increase the grain ration."

DISCUSSION OF THE RATIONS.

The rations given in the preceding have all been fed or are being fed by Wisconsin farmers. The average yield of milk per year for the herds included in the above list is 5,806 lbs. per cow, and of butter 291 lbs. per cow. This is a remarkably good showing and bears evidence that Wisconsin dairymen are aiming toward a high standing of excellence and that some have already reached that goal. When we remember that the average yield of butter per cow for the state is usually placed at 125 lbs. per year, the above average becomes still more creditable.

To be able to give definite expression to the teachings of the preceding rations we shall now summarize the results of the examination of the rations and find out what are average quantities of the nutrients fed. To give no single farmer any advantage, the average ration for each herd has been calculated in the second table, where more rations than one are given by the same farmer. The rations XII and XIII are not included in the summary, as the quantities fed were most likely overestimated. The following tables therefore give a summary of the average daily ration fed to the herds of fifteen Wisconsin dairymen.

Components of Rations for Milch Cows fed by Fifteen Wisconsin Dairymen.

Feeding Stuff.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs,	lbs.
Corn silage......	30	27	40	50	50	35	30	45	60	...	30	32	......	25	35
Clover silage.....	....	....	....	....	....	....	....	.....	....	....	...	22	......	......	....
Clover hay.......	....	6	5½	....	5	....	....	5	....	....	....	2½	5	......	8
Timothy hay... .	...	....	....	....	5	....	...	.....	7	15	....	2½	......	......	3
Mixed hay........	6½	....	...	10	....	5	11	......	....	...	....	....	......	......	...
Marsh hay.......	....	....	...	...	....	....	....	......	...	....	....	...	......	10	....
Fodder corn......	....	8	...	....	....	....	...	......	....	....	....	...	16	......	....
Corn stalks.......	....	....	....	....	....	....	....	......	....	....	13	....	......	20	....
Barley straw.....	....	...	....	...	....	....	....	......	....	14½	....	....	......	......	...
Oat straw........	....	1½	...	....	....	...	4	......	6	....	....	....	......	......	....
Wheat bran	....	4	10	4½	3	2¼	4	8	....	4	3¾	6	5⅓	......	3⅓
Wheat middlings	....	....	....	....	....	....	....	......	....	....	....	....	......	3	....
Corn meal........	....	...	....	...	3	....	...	.....	...	....	3	....	......	......	....
Corn and cob m'l	5	....	....	....	....	....	....	......	....	....	....	....	......	......	....
Oats..............	5	4	....	5½	....	....	2	......	3	3	3¼	4	2⅔	......	2⅓
Cotton seed meal	....	...	....	....	...	1½	...	......	...	..	....	3	......	......	....
Linseed meal	3	....	2	2	1	....	2	2	3	½	....	....	......	3	2⅓
Malt sprouts.... .	....	....	...	....	....	4	...	.....	...	....	....	....	......	......	....
Pea meal.........	....	..	....	....	....	...	...	......	....	....	1	....	......	......	....
Cost of ration,... Cents.....	17.7	14.6	15.2	19.4	14.6	11.9	15.1	14.2	16.5	14.8	13.9	19.1	11.0	13.1	15.1

Summary of Nutrients in Rations Fed by Fifteen Wisconsin Dairymen.

Herd No.	No. of cows in herd.	Breed.	Organic matter in daily ration	DIGESTIBLE. Protein (Nx 6.25.)	Carbo-hydrates.	Fat	Total digestible matter.	Nutritive ratio	ANNUAL PRODUCT PER COW. Milk.	Butter.	Cost of ration
			Lbs.	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.	Cts.
I	60	Shorthorn & Red Polls.	19.61	1.80	10.66	.70	13.16	1 : 6.9	6,000	260	17.7
II	27	Gr. Jerseys*	27.59	2.09	14.45	.75	17.29	1 : 7.7	5,500	320	13.7
III	17	Guernseys...	22.64	2.46	11.26	.76	14.48	1 : 5.3	6,143	.....	15.2
IV	18	Holsteins...	25.18	2.11	13.58	.79	16.48	1 : 7.3	**	...	19.4
V	30	Holsteins....	27.12	1.79	12.49	.70	14.98	1 : 7.8	7,000	300	14.6
VI	16	Gr. Jerseys†	28.00	3.39	15.14	.96	19.49	1 : 4.8	.....	300	15.3
VII	29	Gr. Jerseys and Natives	28.96	2.22	15.12	.76	18.10	1 : 7.6	....	300	15.1
VIII	45	Jerseys and Gr. Jerseys	29.00	2.97	14.83	.96	18.76	1 : 5.7	4,000	....	14.2
IX	31	Gr. Jerseys..	34.81	2.64	18.82	1.03	22.49	1 : 8.0	....	.....	16.5
X	8	Shorthorns..	26.29	1.33	12.50	.46	15.29	1 : 10.9	....	175	14.8
XI	28	Jerseys......	25.85	1.80	14.70	.75	17.25	1 : 9.1	....	350	13.9
XII	30	Guernseys...	24.50	2.87	11.56	.96	15.39	1 : 4.8	7,500	400	19.1
XIII	7	Jerseys and Natives....	22.47	1.75	12.06	.57	14.38	1 : 7.6	4,500	210	11.0
XIV	49	Holsteins & G. Holsteins	25.29	1.77	13.54	.61	15 92	1 : 8.4	....	.....	13.4
XV	25	Jerseys......	24.00	2.28	11.99	.78	15.05	1 : 6.0	....	....	15.1
Average for 15 herds.			***26.09***	***2.22***	***13.58***	***.76***	***16.56***	***1 : 6.9***	***5,806***	***291***	15.3
Standard ration according to Kuehn...			‡20–33.5	§1.5–2.4	12–14	.4–.7	13.9–17.1	1:5.5-8.0	....	.....	....
Standard ration according to Wolff....			24.0	2.5	12.5	.4	15 4	1:5.4	....	.....	...

*Average of two rations. †Average of four rations.
‡Total dry matter. §Albuminoids. **6-16,000 lbs.

A study of the above tables will disclose many points of interest to the student of cattle feeding. It will be noticed that the cost of the ration for a cow in Wisconsin ranges between 11.0 and 19.4 cents, and the average cost is 15.3 cents; this may be taken to represent what it costs to keep

a good cow a day under our conditions, when she is in full flow of milk and receiving a full ration. It may seem an exaggerated figure to many, but there are two points to be considered in this connection, which are often overlooked.

First, the prices upon which the calculations of the cost of the rations have been based are average market prices for our state, and represent what the ration would have cost the farmer if the feeds had been bought in open market; it is evident that where a large share of the materials fed is raised on the farm, their cost is materially lessened to the feeder.

Second, the manurial value of the feed stuffs is left out of account in the calculations. We cannot here enter into any discussion of this subject, but may state that if all the manure from the cows is carefully saved, its value will represent from one half to one-third of the estimated cost of keeping the cows; that is, the fertilizing ingredients contained in the liquid and in the solid manure would be equivalent to the quantities of commercial fertilizers which could be bought for these amounts of money.

Remembering these two points, the average cost of the ration for a dairy cow given above cannot be considered overestimated.

COMPARISON OF FEEDING STANDARDS.

At the end of the last table will be found a statement of the feeding standards for which milch cows recommended by the German scientist Kühn and Wolff. These two investigators who are considered authorities in the science of nutrition of farm animals, differ greatly in their opinions as to the advisibility of adopting a definite standard ration for the different animals; Wolf taking a more dogmatic stand than Kühn, claiming that, for instance, a milch cow in full flow of milch will require 24 lbs. of organic matter, 2.5 lbs of digestible protein, 12.5 lbs digestible carbohydrates, etc., in order to do her best. Kühn, on the other hand, says that according to the stage of lactation period, yield, power

of production of each cow, the quantities to be fed may profitably range from 20 to 33.5 lbs. dry matter, 1.5 to 2.4 lbs. digestible true protein, etc.

If we compare the average ration for fifteen Wisconsin herds with Kühn's standard ration, we are at once struck by the close similarity between the two; in all constituents but one (digestible fat) our average quantities of nutrients come between the extremes of Kühn and near the upper limit of each class of nutrients. The standard ration of Wolff's, on the other hand, which has so extensively been quoted and recommended in this country, contains smaller quantities of all components except digestible protoin, than called for by our average ration, and has therefore a narrower nutritive ratio than the latter.

It has been contended for years by some of our agricultural scientists that Wolff's standard ration for milch cows did not suit our conditions, but for want of any better data, it has always been quoted as the standard by our agricultural writers. The time may now be considered at hand when the subject should be looked into more closely; in doing so we approach the question in a different way than was done by the German investigators, inquiring what is the composition of rations for milch cows that have proved successful with practical feeders in our country?

COMPARISON OF AMERICAN AND GERMAN FEEDING STANDARDS.

In looking around for evidence from this continent of the same kind as gathered from our own state, we find in Eighth Annual Report, New York Experiment Station (Geneva), an account of a number of rations fed by different leading dairymen in the state; a study of the rations and the yields for the respective herds will show that eight of the number given may be considered first-class, profitable rations. Besides these rations we have complete records of the feed eaten by five herds of milch cows in Connecticut (see Connecticut Experiment Station Report 1881, pp. 90–105; 1891, p. 99). We give below the average results of the examination of these rations.

No. of herds.	State.	Dry matter.	Digestible protein	Digestible carbohydrates.	Digestible fat.	Total digestible matter.	Nutritive ratio
15............	Wisconsin....	26.09	2.22	13.58	.76	16.56	1:6.9
8............	New York...	24.59	2.21	12.85	.81	15.87	1:6.6
5........ .. .	Connecticut .	22.60	1.91	12.08	.41	14.40	1:6.8
Average for 28 herds in United States		25.04	2.16	13. 10	.71	15.97	1:6.8

In calculating the average ration for the twenty-eight herds, the figures in each set have been given the value due to them in accordance with the number of herds entering into their calculation. We notice that in all three cases there is a striking similarity between the rations, and although there are some differences for the herds within each state, the average rations fed in each of the three three states was practically the same. This must mean that, under the conditions existing in our country, practical business farmers, with the question of dollars and cents before them, and with no scientific hobby of any kind as their guide, have found that a cow ought to receive such daily rations as will contain about 2.2 lbs. of digestible protein, 13.1 lbs. digestible carbohydrates, and .7 lbs. digestible fat, in order to produce a large flow of milk at the most profit; such rations will have a nutritive ratio of about 1:6.8.

It would appear then that our cows need less protein in their ration to do their best, and more carbohydrates and fat than is recommended by Wolff; if this holds good, the German standard ration is not applicable to our conditions and ought not to form the basis for calculations of the proper amounts to feed our milch cows. *Atwater* found similar differences in the dietaries of men in this country and in Europe, and explains it by the one sidedness of our agricultural production, our fodders and feeds being nearly all comparatively low in protein and high in carbohydrates and fat.

If we consider the data from the Wisconsin herds, we notice that the more nitrogenous rations generally yield the

largest returns; local conditions will determine, however, which fodder can be most profitably fed. At the ordinary market price of cattle foods at the disposal of our farmers it is believed that the more carbonaceous feed stuffs like corn, corn silage, fodder corn, and hay, and feeds like clover hay and oats, will be found to be more economical with us. While there can be no doubt but that, other conditions being equal, a nutritive ratio of 1:4 or 5 will as a general rule produce a larger flow of milk than one of 1:7 or 8, it is usually better economy for us to feed more heavily of a somewhat wider ration, sacrificing a small increase in yield which would result from the feeding of the narrower ration, on account of the increased cost of the feed. Where local conditions are such, however, that nitrogenous feed stuffs can be procured at only slightly increased cost above that of more carbonaceous foods, it is good economy to feed them; for the same reason each farmer ought to raise on his farm and feed as much of the foods rich in nitrogenous principles as possible, like legumes and oats, and thus increase the effectiveness of the rations fed to his cows.

The nutrients in the rations given in the preceding table were calculated on basis of the average composition and digestibility of our feeding stuffs and determined through analysis and experiments by American and foreign experiment stations. In some cases the quantities of fodders fed and the average weight of cows were only estimated. For this and other reasons which can not be explained in details, the nutrients in in the standard ration are only approximations. From the very character of the problem, more exact data would not be of much greater value, however, for as we shall see presently, the demands of each cow for food sufficient to do her best, will vary greatly, and the standard ration can only be a guide, above or below which profitable rations may be constructed to suit each particular case. It is therefore believed that the ration given will serve the purpose for which it is intended as well as if all the feeds had been analyzed, their digestibility determined in each case, and

the thousand and one precautions taken which are necessary to obtain a true solution of a scientific problem.

LIMITATIONS OF FEEDING STANDARDS.

We have here to deal with the feeding standard for milch cows in full flow of milk, but the same principles hold good for all. From what has been said, it is clear that the feeding standard is not intended to be an infallible rule, always securing the best results to the feeder. No two animals have exactly the same capacity for assimilating food, nor has the same animal the same power of converting the food into milk constitutents at different stages of the same period of lactation. No feeding standard can therefore supplement the judgment of the good feeder; each cow must receive a supply of food according to her peculiar requirements; some cows may be stimulated by high feeding, and the farther they can be driven in this direction, up to a certain limit, the more profit they will bring their owners, while others will lay on flesh by such feeding, and their power of milk production will decrease. The standard ration may, however, be useful as a general guide and a help to a rational system of feeding. It will allow of considerable latitude either way; the milking qualities of the cows as well as the market prices of the different feed stuffs and of the dairy products will largely determine whether more nitrogenous or more carbonaceous feed stuffs may be fed to advantage. The standard ration as given above will, we believe, show the average quantities of nutrients necessary to produce economically a large flow of milk under our present conditions; it does not offer to do away with intelligence on the part of the feeder beyond some adeptness for figures, but it calls into service his best judgment in his work.

HEAVY FEEDING PAYS.

If we compare the yields of milk or butter given in the table on p. with the rations fed in each case, we notice that the largest yields of milk or butter occur when the

heaviest rations were fed; and also that the rations containing the largest proportions of digestible protein seem the most effective, other conditions being equal. It is not only a question of supplying a large quantity of nutrients in the ration, but to supply a reasonable quantity of nitrogenous nutrients as well; a comparison of rations X and XII will illustrate this.

The table bears decided evidence that heavy feeding pays. While all the rations doubtless furnished ample nutriment for the cows, those low in organic matter or in digestible matter did not supply much above the needs of the system, and the product is consequently low. According to German experience, it takes 8.85 lbs. digestible matter to keep a steer of a thousand pounds live weight for a day without his losing or gaining in flesh; the same may also apply approximately to a dry cow; the same authorities estimate that a cow in full flow of milk will need 15.4 lbs. of digestible matter daily in her food, hence we may consider nearly 60 per cent. of the food of a cow as necessary to maintain her body; or, to put it in a different way, a cow producing a full flow of milk ought to receive over 70 per cent. more food than is required to keep her at maintenance.

Many farmers feed their cows only a pittance above what they need for their maintenance; they fail to realize that their profits cannot begin until after this point has been reached. The more the cow will assimilate in excess of that required to maintain her body, the better, as this excess may be used directly for the production of milk. We therefore see that with the right kind of cows, the more we feed, up to the limit of the capacity of each animal the better returns may be obtained, relatively as well as absolutely; hence an expensive ration is by no means necessarily an unprofitable one.

What has been here said of dairy cows applies with equal force to all farm animals; it is the excess above what is required for maintenance that yields returns to the feeder. When we remember that a cow as a rule is supporting a calf during the greater part of her period of lactation, and is

thus asked to do double work during all this time, the plea for liberal feeding will seem all the more reasonable.

We have considered so far the feed of the dairy cow; space will forbid more than a mere mentioning of the other side of the question, the necessity of keeping cows in the herd that respond to generous feeding. This is of course of no less importance, and still we believe that most farmers have cows in their herds that will do considerably better under more liberal system of feeding; if they study their cows individually and weed out the poor ones, feeding those generously that show their ability to assimilate larger quantities of food than they now receive, by an increase in the milk yield, they will no doubt be able to do as well as many of the dairymen whose rations are given in the preceding. At the same time care must be taken to feed nothing to waste, to feed all that the cows can utalize and no more.

IN CONCLUSION.

The investigation described in the preceding pages is being continued during the present season, and it is believed that the results obtained will be of considerable value to feeders of dairy cattle. Until more data have been accumulated, the following daily ration may be considered a standard American ration for milch cows in full flow of milk, weighing about 1,000 lbs. Being founded on practical American feeding experience, its adoption is recommended as a basis for calculation of rations for milch cows under our conditions, in preference to Wolff's standard ration, now generally used.

Organic matter.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Total digestible matter.	Nutritive ratio.
lbs. 25.0	lbs 2.2	lbs. 13.1	lbs. .7	lbs. 16.0	1:6.8

Most of the rations given in the preceding pages may be recommended to Wisconsin farmers. Applying our best knowledge on the subject to the conditions present in our

state we further believe that the following six rations are worthy of trial; it is presumed that they will meet the wants of our farmers and that with the right kind of cows, good results will follow their feeding. No practical dairyman can weigh out the several constituents of a ration each day for each animal in the herd; let him use the scales in determing what certain measures hold, and then use these for distributing the food among the members of the herd.

RATION I.—Corn silage, 40 lbs.; clover hay, 8 lbs.; wheat bran, 6 lbs.; corn meal,, 3 lbs.

Cost of ration, 14.3 cts.

Total organic matter	24.44 lbs.
Digestible protein	2.01 lbs.
Digestible carbohydrates	13.23 lbs.
Digestible fat	.75 lbs.
Total digestible matter	15.99 lbs.

Nutritive ratio, 1:7.4.

RATION II.—Fodder corn, 20 lbs.; hay, 6 lbs.; oats, 4 lbs.; shorts, 4 lbs.; oil meal, 2 lbs.

Cost of ration, 15.3 cts.

Total organic matter	25.60 lbs.
Digestible protein	2.10 lbs.
Digestible carbohydrates	14.49 lbs.
Digestible fat	.75 lbs.
Total digestible matter	17.34 lbs.

Nutritive ratio, 1:7.7.

RATION III.—Corn silage, 50 lbs.; corn stalks (stover), 5 lbs.; oats, 6 lbs.; malt sprouts, 4 lbs.; corn meal, 2 lbs.

Cost of ration, 15.6 cts.

Total organic matter	25.25 lbs.
Digestible protein	2.13 lbs.
Digestible carbohydrates	13.69 lbs.
Digestible fat	.78 lbs.
Total digestible matter	16.60 lbs.

Nutritive ratio, 1:7.2.

RATION IV.—Clover silage, 30 lbs.; hay, 15 lbs.; wheat bran, 3 lbs.; corn meal, 3 lbs.; cotton seed meal, 2 lbs.

Cost of ration, 16.2 cts.

Total organic matter	26.32 lbs.
Digestible protein	2.53 lbs.
Digestible carbohydrates	12.97 lbs.
Digestible fat	.77 lbs.
Total digestible matter	16.27 lbs.

Nutritive ratio, 1:5.8.

RATION V.—Timothy hay, 10 lbs.; clover hay, 10 lbs.; wheat bran, 6 lbs.; oats, 6 lbs.

Cost of ration, 17.3 cts.

Total organic matter	26.19 lbs.
Digestible protein	2.26 lbs.
Digestible carbohydrates	13.21 lbs.
Digestible fat	.70 lbs.
Total digestible matter	16.17 lbs.

Nutritive ratio, 1:6.5.

RATION VI.—Fodder corn, 20 lbs.; clover hay, 8 lbs.; oats, 6 lbs., oil meal, 3 lbs.

Cost of ration, 16.4 cts.

Total organic matter	27.35 lbs.
Digestible protein	2.40 lbs.
Digestible carbohydrates	14.12 lbs.
Digestible fat	.85 lbs.
Total digestible matter	17.37 lbs.

Nutritive ratio, 1:7.0.

The teachings of this investigaton may briefly be stated as follows:

Keep only cows that respond to good feeding.

Feed liberally, but not to waste.

Select such feed stuffs as will supply a fair quantity of protein.

Raise and feed more oats and clover; use bran, shorts and oil meal whenever needed and when obtainable at reasonable prices.

THE AMOUNT OF WATER REQUIRED TO PRODUCE A POUND OF DRY MATTER IN BARLEY, OATS, CORN, CLOVER, AND PEAS IN WISCONSIN.

F. H. KING.

Each step forward, taken either by science or practice, toward a better understanding of the great roll played by soil-moisture in the growth of vegetation serves only to show that we have much yet to learn before its functions are fully understood, and before methods of tillage can be placed upon a thoroughly rational basis. Practical experience is proving to market gardeners east of the Mississippi river, where there is a mean annual rainfall of 35 to 45 inches, and fairly distributed through the growing season, that the amount of water required for the largest returns their lands are capable of producing is greater than the natural rainfall supplies when one year is taken with another, and many of them are now turning their attention toward methods of irrigation with remunerative results. From the practical standpoint therefore, as well as from the purely scientific, it is of importance to know the amount of water which our various cultivated crops need to mature heavy yields.

The experiments relating to this subject which were conducted at this Station in 1892, and recorded in the Eighth Annual Report, were repeated this season with two additional crops, red clover and field peas.

PLAN OF THE EXPERIMENT.

The experiments of this season were conducted on essentially the same plan as were those of last year, and illustrated in Fig. 4, page 125 of that report. Instead of using 50 gallon vinegar barrels in which to place the soil, galvinized iron cylinders 18 in. inside diameter and 40 inches deep

were substituted in order to avoid all except surface evaporation from the soil. These cylinders were placed in pits with their tops flush with the surface of the ground, in fields surrounded with growing crops of the same kind; they were weighed from time to time with a specially constructed weigh-masters beam sensitive to one-tenth of a pound when carrying a weight of 600 lbs. This year, too, as was the case last, each experiment was conducted in duplicate.

The experiments with red clover were conducted in two of the barrels used last year, one for oats and the other for barley, and were seeded in the spring of that year and wintered over in the barrels, litter being packed about the barrels in the cavity in which they stood to prevent excessive freezing, and the surface sheltered from rain and snow. The clover wintered perfectly in this condition, and produced a thoroughly normal growth during the season. During these experiments no effort was made to check surface evaporation from the soil, the object being to ascertain the amount of water required for a crop including the necessary loss of water through evaporation from the surface of the soil in which the crop is grown. When the soil in the cylinders was likely to become too wet from the natural rain, shelters were provided to exclude it, otherwise the cylinders were exposed to the weather night and day.

It was found by careful weighing just before and after rains, that the catch of water by the several cylinders did not materially differ among themselves and that they corresponded very closely to the results indicated by the rain gauge and readings of the rain gauge have been used in computing the amount of water derived from this source by the plants under experiment.

From time to time, as the cases required, water was added, in weighed quantities, to the several cylinders the effort being to maintain the weight, in the several cases, very near that at seeding time, when the moisture was such as to give the soil good tilth. The surface of the ground was stirred in the case of the corn, to correspond with the field conditions, but otherwise no effort was made to check surface evaporation.

THE AMOUNT OF WATER REQUIRED FOR A POUND OF DRY MATTER IN WISCONSIN.

This season one sample in each case was reserved for permanent exhibition in the museum and was not mutilated for purposes of determining the ratio of dry matter produced to the amount of water consumed.

In the following table are given the observed amounts of dry matter produced and the amounts of water required, both for 1891 and for 1892.

Table showing the amount of water required for a pound of dry matter in Wisconsin.

	Lbs. of water used.	Lbs. of dry matter produced.	Lbs. of water per pound of dry matter		Computed yield per acre.	Computed amount of water used.	
				Mean.	Lbs.	In tons per acre.	In inches.
1891.							
Barley.... 1	158.3	.3966	399.14	401.74	7441	1494.67	13.19
Barley.......... 2	141.03	.3488	401.33				
Oats 1	224.25	.4405	509.31	501.47	8861	2221.76	19.69
Oats.. 2	220.7	.4471	493.63				
Corn............ 1	300.45	1.0152	295.95	301.49	19845	2991.53	26.39
Corn 2	298.65	.9727	307.03				
1892.							
Barley 1	216.12	.576	375.21	375.21	14196	2663 89	23.52
Barley 2	206.12						
Oats........... 1	174 6	.3322	525.59	52.559	8189	2152.11	19.00
Oats 2	167.58						
Corn........... 1	235.96	.9905.	325.96	316.9	19184	2842.37	25.09
Corn 2	225.24	.5657	398 15				
Clover.......... 1	337.36	.5977	564.43	564.43	12486	3367.84	29.73
Clover.......... 2	348.66						
Peas 1	155.24	.3252	477.37	477.37	8017	1913.48	16.89
Peas............ 2	139.17						

It should be stated before discussing this table that the oats did not do quite as well in the cylinders as they did in the field, nor quite as well as they did in the barrels in 1891. The crop of barley was, however, much better both in the field and in the cylinders than it was the previous year. Only two stalks of corn were allowed to grow in each cylinder this season, while in 1891 four matured in each barrel, and the result was a heavier earing, each stalk this year maturing a good ear. The plants in one cylinder did not do as well as did the corn in the field, the stalks being shorter and the ears smaller than the average for the field. In the other case the two stalks with their ears were fully up to the average from the field.

If for any reason a crop does not develop normally, the amount of evaporation from the surface of the ground is likely to be both absolutely and relatively larger per pound of dry matter produced than in the case of the larger yields; and this fact should be borne in mind in studying the figures given in the table, and more especially those for the corn in 1892.

It will be noted in the first place that the oat crop, when compared with the barley used relatively much more water for a pound of dry matter produced both in 1891 and in 1892, the average of the three trials for oats being 513.52 lbs., while that for the barley was only 388.48, or 125 lbs. of water less for a pound of dry matter in the case of barley than in the case of the oats, and since the yield of dry matter to the acre of oats is likely to be as great or even greater than with the barley, it is evident that the oat crop must exhaust the soil of moisture to a much greater extent than does that of barley, and there is good reason for believing that this difference explains in a large measure why seeding ground to clover is likely to be much more successful with barley than with oats.

It will be observed in the second place, that the corn crop, the great American staple, has during these trials consumed less water per pound of dry matter than either of the other crops, the average of the four cases being only

309.2 lbs., as compared with 388.48 for barley, 477.37 for peas, 513.52 for oats and 564.43 lbs. of water for one pound of dry matter in clover. One of the chief reasons, in my judgment, for the relatively small consumption of water by corn is to be found in the fact that much less water is lost from the soil by direct surface evaporation on account of surface cultivation during so much of the growing season.

It is quite probable that the relatively large consumption of water by the clover shown by the single trial is more apparent than real, because it seems quite likely that the evaporation through the sides of the barrels during the second year's service may have been considerable.

FIELD EXPERIMENT WITH CORN.

In the field of corn in which the two cylinders were placed, the water content of the soil was determined down to a depth of four feet, in the spring at the time of planting, and again at the end of the growing season. The yield of dry matter per acre was also very carefully determined. One portion of this ground was manured, while another portion was not, and the average amount of dry matter per acre was 6351 lbs. on the unmanured ground, and 7740 6 on the manured ground.

The mean amount of water in the soil near the time of planting for each column of soil one square foot in section and four feet deep was 88.09 lbs., and at the time of harvesting it was 74.78 lbs. on the unmanured ground, and 74.47 lbs. on the manured ground. There was therefore a loss of water from the soil amounting to 13.31 lbs. on the unmanured ground and 13.62 lbs. on the manured.

The total rainfall during the growing season was 100.29 lbs. per sq. ft. A large amount of this rain, 10.5 in., or 54.6 lbs. per sq. ft. fell between the time of planting and June 30, when the corn was yet small, and must have been mostly lost by percolation. Supposing this amount to have been lost in this way during the season, the amount of water used per sq. ft. must have been 59 lbs. for the un-

manured, and 59.3 for the manured ground. Under these conditions it must have required 404.6 lbs. of water for a pound of dry matter on the unmanured, and 333.7 lbs. on the manured ground, while the average in the cylinder was 316 lbs. of water for a pound of dry matter.

RELATION BETWEEN THE AMOUNT OF DRY MATTER PRODUCED AND THE NUMBER OF INCHES OF WATER CONSUMED.

In the last annual report, page 130, attention was called to the fact that while the yields of dry matter calculated per acre of the crops grown in the cylinders were very much greater, in every case, than were those grown under field conditions, yet the amount of water used in each case was also very much greater when expressed in inches of rain. This year the differences are as strongly marked as they were last, and in the same direction, and this makes it desirable to bring them together for comparison as given below:

	In the Field.		In Cylinders	
	Dry matter per acre.	Water in inches.	Dry matter per acre	Water in inches.
Oats.				
1891	6083 lbs.	13.93 in.	8861 lbs.	19.6 in.
1892	....	....	8189 lbs.	19.0 in.
Barley.				
1891	4157 lbs.	11.27 in.	7441 lbs.	13.19 in.
1892	....	....	14:96 lbs.	23.52 in.
Corn.				
1891	8190.5 lbs.	12.26 in.	19845 lbs.	26.89 in.
1892	7045.3 lbs.	11.34 in.	19184 lbs.	25.09 in.

With this grouping it becomes very apparent that the yield of dry matter per acre for the three crops are measurable proportional to the number of inches of water con-

sumed during their growth. Taking the cases of the crops grown in the cylinders the nearly equal yields of corn, and of oats in 1891 and 1892 are associated with nearly equal amounts of water used per unit area, but the smaller yields are associated with the smaller amount of water. In the case of the barley where the yield in 1892 is nearly double that of 1891, the depth of water supplied was also nearly doubled.

These results point very strongly toward the conclusion that we rarely have water enough in our soils under natural conditions to realize even approximate possible returns from our land, and that were we prepared to irrigate almost any of our crops at such times as there is a deficiency of water in the soil, very much larger average yields would be secured.

INFLUENCE OF DEEP AND SHALLOW CULTIVATION ON THE WATER CONTENT OF THE SOIL.

F. H. KING.

During the past season, and also the year before, an experiment was conducted to determine the relative yields of corn under treatment of deep and shallow cultivation, and in connection with the experiment of the present year a study was made of the changes in the water content of the soil.

Two kinds of cultivators were used, the Deers Eagle Claw for the deep cultization and the Tower cultivator for the shallow. The Eagle Claw was set so as to penetrate steadily to a depth of 3 inches, while the Tower was set so as to slice off and lay back upon the surface somewhat less than one inch of earth, on the average, at each cultivation. The soil experimented upon was a clay loam, thoroughly tile drained at a depth of four feet and the surface sloped toward the north about two feet in 400. The level of the water table at planting time was about four feet below the surface and from 5 to 6 ft. at the time the corn was cut. The corn was planted in north and south rows 3.5 feet apart and every alternate three rows were cultivated shallow and the remainder deep.

Before the corn was planted, on May 16th, samples of soil were taken in two-foot sections to a depth of four feet in three lines extending lengthwise of the field, on a strip 36 feet wide lying immediately adjacent to the corn grown but which was held fallow for another experiment. Eleven samples were taken in each line midway between each line of tile which are 33 ft. apart.

The mean per cent. of water in the eleven samples of each strip is given below:

	East strip.	Middle strip.	West strip.
First and second foot	25.77 per cent.	25.40 per cent.	26.03 per c.
Third and fourth foot	22 87 per cent.	22.62 per cent.	22.80 per c.
Mean	24.82	24.01	24.42

These figures will serve to show the amount of variation which may be expected in the per cent. of water in soils receiving identical treatment.

On August 27 samples of soil were taken in one-foot sections down to a depth of five feet on two immediately adjacent plats of corn, one being cultivated shallow and the other deep. Each sample was a composite of eight taken along a line in the center of each plat, and the table below expresses the results of the determinations:

Table showing the per cent. of water in corn ground cultivated shallow and cultivated deep.

Depth of Sample.	Deep Cultivation.	Shallow Cultivation.
Ist foot	24.09	22.85
2nd foot	18.75	18 08
3rd foot	18 94	17.88
4th foot	21.18	18.97
5th foot	22.11	20.31
Mean	21.01	19.61
Difference	1.40	

It will be seen from this table that not only is the difference between the mean per cent. of water in the deep and shallow cultivated ground more than three times as large as that observed in the spring, but there is no exception, in the five sets of samples, to the deep cultivated ground being more moist than the shallow.

At the time the corn was cut, September 16th, a similar set of samples was again taken with the results expressed below:

Table showing the per cent. of water in corn ground cultivated shallow and cultivated deep.

Depth of Sample.	Deep Cultivation.	Shallow Cultivation.
1st foot	23.14	22.70
2nd foot	23.30	21.08
3rd foot	21.94	19.65
4th foot	22.46	19.58
Mean	22.71	20.70
Difference	2.01	

The two plats from which these samples were taken were not the same as those from which the others were procured, and yet the difference in the per cent. of water in favor of the deep cultivation is five times as great as that observed in similar taken samples in the spring. Further than this, there are no individual exceptions to the deep cultivated ground being more moist than the shallow in the four pairs of samples.

In the last Annual Report of this Station pp. 104,111, a similar experiment is recorded comparing, on fallow ground, deep cultivation with no cultivation. In this case as in the last two, the soil cultivated deep was decidedly more moist. Taking all things together, the evidence is both cumulative and strong that these observed differences in the per cent. of water in the soil have been due to the differences in the physical treatment of the surface. It is worthy of special emphasis here, not only because of the practical bearing these results have upon the problems of surface tillage, but also because of the lessons they teach in regard to methods of investigation in soil physics, that the entire depth affected by the roots of cultivated crops, to and even beyond five feet, may be measurably affected in the quantity of water it holds by differences in methods of surface tillage.

There appear to be at least two causes which have brought about the observed differences in the water content of these soils, one of which was cultivated shallow and the other deep. The first is the difference in the rate of surface evaporation from soil-mulches of different depths. When a wet soil is stirred at the surface the first effect is a rapid drying of the stirred soil, first, because the surface exposed to the air is greatly increased, and second because the capillary connection with the moist soil below has been partially broken. When this stirred soil becomes once dry, the capillary movement upward through it is still further and very greatly impeded, making it in this condition a very affective mulch, and the loss of moisture through a deep mulch of this character is less than it is through a shallow one.

The second cause of the observed differences appears to be a difference of soil temperature, brought about by the unequal shading influence of mulches of different thickness. It is shown in the Seventh Annual Report of this Station, pp. 121–123, that a firm smooth surface like that produced by rolling warms more rapidly and deeply than one covered with a mulch like that produced by surface tillage. In another part of this report, page 194, it is shown that even the diurnal changes in soil temperature cause the capillary water to alternately rise and fall as the soil temperature changes. When the soil becomes warm its water-holding power decreases and the capillary water drops to a lower level; then as its temperature falls again it can lift water higher so that even the tile drains on the Experiment Station farm discharge water faster or slower as the soil warms or cools.

We are as yet without adequate data showing to what extent surface tillage influences soil temperature at considerable depths below the surface, but since its influence is large near the surface, it may be expected to be measurable at depths of three to four feet, and if this is true the reason why thorough cultivation in dry seasons is so advantageous become evident enough. The case stands like this:

1. Thorough cultivation greatly diminishes surface evaporation from the soil.

2. Thorough cultivation keeps the soil below the surface cooler and this materially strengthens the capillary power so that less water percolates downward out of the reach of root action.

3. The capillary force being stronger the soil moisture is moved upward faster and through longer distances as the roots of growing crops consume it, and thus more water becomes available.

INFLUENCE OF FARM YARD MANURE ON THE MOVEMENT AND AMOUNT OF WATER IN SOIL.

F. H. KING.

In the last Annual Report of this Station, pp. 111–120, is recorded a field study of the influence of farm-yard manure on the movement and amount of water in the soil, of both fallow ground and that upon which corn was grown. In that investigation, for the fallow ground, it was found, after a certain interval of time, that while the total amount of water in the upper six feet of soil was essentially equal on both the manured and unmanured ground, yet there was a marked difference in the distribution of it, the upper three feet of the manured ground being decidedly more moist and the lower dryer than the unmanured. At the close of the season the manured ground was more moist throughout the entire depth, although the largest difference still existed in the upper three feet. In the case of the ground producing corn it was found that while that which was manured was dryer than the unmanured ground, yet the difference was much too small to account for the increased yield of dry matter, there being a difference demanded of 7.92 lbs. per sq. ft., while the observed difference was only 3.85 lbs., and the inference was that farm-yard manure, in some manner tends to leave the surface soil more moist at the end of the growing season, and possibly to increase the upward capillary movement of soil water.

The present season these experiments were repeated in essentially the same manner as last year, and upon similar ground; the one difference being that the plats were larger and extended north and south in the direction of the slope of standing water in the ground, instead of east and west as they did the season before.

On the fallow ground samples of soil were taken in the

usual manner, each being a composite of 8 to 11. There were three of these plats, each 12 ft. wide lying side by side, the middle one being manured. On May 16, before this ground was plowed, and before the manure had been applied, samples of soil were taken in two-foot sections down to a depth of four feet in eleven transverse rows across the three plats, each sample being taken from the center of the respective plats. Below are given the percentages of water found in the soil at this time for each of the eleven lines of samples.

Table showing per cent. of water in the soil May 16 before the application of farm-yard manure.

Depth.	Series.	East Plat.	Middle Plat.	West Plat.
Surface two feet	1	21.90	23.78	24.81
	2	25.58	25.60	25.64
	3	25.50	23.07	26.47
	4	25.63	25.88	26.10
	5	26.01	25.78	25.57
	6	25.99	26.42	27.68
	7	25.78	25.73	25.80
	8	26.59	26.50	26.71
	9	26.01	25.77	25.27
	10	26.46	26.02	26.06
	11	25.16	25.04	26 21
Average	....	25.77	25.40	26.03
Second two feet	1	20.18	18.26	19.91
	2	20.73	21.59	21.22
	3	21.15	26.79	21.69
	4	25.02	22.21	24.05
	5	21.30	21.88	21.86
	6	22.58	23.00	20.80
	7	24.98	23.15	23.38
	8	23.66	25.13	23.71
	9	22.13	25.07	25.99
	10	26.14	23.54	23.05
	11	24.77	18.17	25.15
Average	....	22.87	22.62	22.80
General average	....	24.32	24.01	24.42

This table will serve as a basis of comparison for samples taken later on the same ground after the manure has been applied.

After a heavy dressing of cow manure had been applied to the middle of the three plats and plowed under to a depth of five inches, the whole ground was frequently stirred to a depth of two to three inches to keep the surface free from weeds.

On July 13, samples of soil were again taken in one-foot sections down to a depth of four feet, from the centers of each plat in eight transverse series, making each sample a composite of eight, and below are given the percentages of water found in each foot on that date.

Table showing the per cent. of water in manured and unmanured ground on July 13, 58 *days after the application of the manure.*

Depth.	East Plat.	Middle Plat.	West Plat.
	Not manured.	Manured.	Not manured.
First foot	21.27 per cent.	25.89 per cent.	24.44 per cent.
Second foot	23.62 per cent	21.01 per cent	24.11 per cent.
Third foot	23.52 per cent.	23.72 per cent.	23.25 per cent.
Fourth foot	23.32 per cent.	23.74 per cent.	23.82 per cent.
Average	23.68 per cent.	24.34 per cent.	23.78 per cent.
Mean difference		.61 per cent.	

On August 30, samples of soil were again taken on the same plats and in the same manner, with the following results:

Table showing the per cent. of water in manured and unmanured ground August 30.

Depth.	East Plat.	Middle Plat.	West Plat.
	Not manured.	Manured.	Not manured.
First foot..................	24.71 per cent.	25.64 per cent.	24.82 per cent.
Second foot	24.80 per cent.	24.42 per cent.	24.39 per cent.
Third foot...........	24.03 per cent.	24.21 per cent.	23.45 per cent.
Fourth foot.....................	22.29 per cent.	21.69 per cent.	21.15 per cent.
Average.....................	23.83 per cent.	23.99 per cent.	23.45 per cent.
Mean Difference	....	.35 per cent.	....

It will be seen from these three tables that the water content of the soil under investigation remained remarkably constant throughout the season. The very close agreement of these results among themselves show in a conclusive manner that the method of obtaining them is so accurate that comparatively small differences in results may be allowed to have a real significance in discussion.

It is evident enough from these tables that during the present comparatively wet season the farm-yard manure has had a much less marked influence upon the water content of the soil than was shown during the dryer season of last year. The results, however, small as the differences are, do show a measurable influence of the farm yard manure in leaving the soil at the end of the season more moist than without its application, and this, too, down to a depth of four feet at least. If it is allowed, as I think it must be, that the general averages in the three tables presented represent the actual relative amounts of moisture in the upper four feet of the three plats on those dates, it follows that the manure had the effect of changing the water content on the manured ground so as to make a relative increase in the manured soil of

$$.36 + .61 = .97 \text{ per cent.}$$

on July 13, and of

$$.36 + .35 = .71 \text{ per cent.}$$

on August 30; a difference of 3.7 lbs. of water per square foot on the former date, and of 2.7 lbs. on the latter for each column of soil four feet deep.

On April 11, soon after the frost was out of the ground, and before many of the spring rains had fallen, samples of the soil were taken in one-foot sections down to a depth of six feet on each of the four plats experimented with last year to ascertain if any difference in the water content of the soil was measurable at this time. The result showed that the surface foot was still .57 per cent. more moist than the unmanured ground, and that the whole column of soil 6 ft. long had an average of .24 per cent. more water than the unmanured soil did.

In the case of the manured and unmanured ground which produced corn the present year the former yielded at the rate of

$$7740.6 - 6351 = 1389.6 \text{ lb.s}$$

more dry matter to the acre than did the latter, and yet the manured ground contained at the time of harvest in the upper four feet of soil only

$$74.78 - 74.47 = .31 \text{ lbs.}$$

less water than the unmanured soil did for each column four feet long and one square foot in section. But if we suppose that the corn in the field consumed water at the mean rate observed for the corn grown in the cylinders, there should have been an observed difference in the water content of the field soil amounting to 10.08 lbs. per sq. ft. instead of the actual difference of .31 lbs. Here again, as was the case last year, it appears that there must have been

$$10.08 - .31 = 9.77 \text{ lbs.}$$

of water brought up from the supply of permanent water in the ground unless, first, a pound of water on manured ground yields more dry matter than on unmanured ground, or second, unless the evaporation from the surface of the manured ground was less than that from the unmanured.

The present season two cylinders of galvanized iron 18 in. in diameter and 42 in. deep were filled, on July 1, with

a thoroughly mixed clay loam to within one inch of the top, care being taken to add equal weights of soil to the two cylinders each time, and to firm them alike. When the two cylinders were filled to within 6 in. of the top a layer of farm-yard manure was added to one, the quantity being at about the same rate as that applied for the field experiment. Five inches more of soil were then added, when the manured cylinder was found to contain 567.3 lbs. and the unmanured 570.7 lbs. These cylinders were allowed to stand in pits on the fallow ground with their tops flush with the top of the ground where they received the natural rainfall, and were weighed from time to time in the manner already described. On October 13, the manured cylinder weighed 613.8 lbs., or 5.5 more than when filled; the other weighed 608.7 lbs., or 3.3 lbs. less than when filled, thus making it appear that the manured cylinder lost 8.8 lbs., or 4.98 lbs. per square foot less than did the unmanured cylinder during the interval of 105 days. This difference is

$$4.98 - 2.7 = 2.28 \text{ lbs.}$$

greater than the difference observed in the fields for about the same number of days. This difference, however, is in the direction which should be anticipated, because the surface of the soil in the cylinder was not stirred while that in the field was frequently cultivated; and the surface of the soil in the cylinders would naturally become warmer than that of the field and thus tend to increase the evaporation. It will be observed, however, that the diminished evaporation from the manured cylinder is not quite half large enough to account for the increase in dry matter on the manured ground in the field, so that there still remains an effect of the manure in crop production unaccounted for by a difference in the rate of surface evaporation.

NATURAL DISTRIBUTION OF ROOTS IN FIELD SOILS.

F. H. KING.

During the present season a preliminary study was begun, aiming to procure specimens illustrating the actual extent and manner of root penetration and development in field soils under normal conditions of tillage. The first and main object in procuring these specimens was to secure something concrete, something tangible, and at the same time something in real life which could be used in helping students to appreciate the force of some of the maxims of tillage and fertilization of soils in reference to crop production. The universal surprise which the samples thus far collected have been to even our best informed and most experienced farmers who have seen them only serves to emphasize the need of them and to show how inadequately either the horizontal or vertical extent of the root systems of our cultivated crops is appreciated.

DISTRIBUTION OF CORN ROOTS IN NATURAL SOILS UNDER THE CONDITIONS OF FIELD CULTIVATION.

In this study of the distribution of corn roots an effort was made to preserve all of the roots which occupied a given section of soil as nearly as possible in their relative positions after removal. The method of procuring the samples and of fixing the roots in place was as follows:

With a spade a trench two feet wide was dug so as to leave a prism of soil one foot thick and extending at right angles across two rows of corn, one hill of corn was thus left standing at each end of the prism. The trench was deepened until by inspection it was evident that all roots

had been passed. A cage was now made of galvanized iron and wire netting, just large enough to set down over the prism of soil, and when this was in place sharpened wires were forced through the prism of soil in parallel lines along the meshes of the netting, the wires being long enough to reach through and fasten to the netting at each end. The loose soil at the surface of the ground was removed and replaced by casting in its place a block of plaster of paris to represent the surface of the ground. At this stage a force pump throwing a stream of water about 1-16 of an inch in diameter was used to wash the soil away from the roots, leaving them suspended by the wires and held very nearly in the true relative positions they had occupied in the soil in which they grew.

In the manner described samples of corn roots were taken at four different stages of growth, two of which are shown by the photo engraving, Figs. 9 and 10. The first sample was taken July 9, 42 days after planting, when the tops had attained a height of about 18 inches. At this stage the roots of the two hills met and passed each other in the center of rows 3 ft. 6 in. apart, and had penetrated to a depth of about 18 inches. It was found that the surface roots sloped gently downward toward the center of the row where those nearest to the surface were some 8 inches deep. When the corn had attained a height of nearly 3 ft. at the time of the last cultivation, the sample shown in Fig. 9, was taken. Here the roots are seen to occupy the entire soil down to a depth of two feet, which is the height of the cage. At this stage the surface leaders descend in a gentle curve toward the center of the row where they pass one another and lie only 6 in. deep.

Just as the corn is coming into full tassel a third sample was taken which is represented in Fig.10, and here it will be seen the roots have fully occupied the upper three feet of soil in the entire field. In the center of the row, too, the surface leaders have risen still higher, and a few of them are now scarcely five inches deep, though the great bulk of them are still 6 inches or more below the surface at the center.

When the corn had reached maturity one other sample was taken, and in this case a cage four feet deep was required, for the roots reached to and even beyond the bottom. At the center of the row, too, the surface leaders had risen to within four inches of the top of the ground. Nothing can illustrate more forcibly than these samples how deeply and how broadly this great American food plant is able to send its roots foraging through the soil. Not one-half of the actual root surface which occupied the soil is shown in the engravings because it was chiefly only the leaders or main trunk roots which were preserved in the sample. Each of these trunk roots or leaders sends out from opposite sides, much as the stalk does its leaves, slender rootlets from 2 to 6 inches long, and from the surface leaders these slender rootlets stretch directly upward toward, and nearly reaching the surface in the latter part of the season.

Now when it is remembered that during the time this wonderful plant is extracting almost wholly from the passing air, through the instrumentality of the sunshine of summer, from three to four tons of dry matter for every well-tilled acre, its roots are required to pump from the same area from 300 to 400 tons of water, is it strange that there is scarcely a cubic inch of soil in the upper four feet of the field but has one or more rootlets drawing water from it with the food elements it contains?

II. CORN ROOTS FROM NINE TO TWENTY-SEVEN DAYS OLD.

In connection with the study of corn roots described above an effort was made by a different method to procure samples showing the natural position and development of the roots at three earlier stages of growth, nine, eighteen, and twenty-seven days from planting. Two of these samples are shown by the photo-engravings, Figs. 11 and 12.

The method used here was to have three series of circles, 18, 24, and 30 inches in diameter, across which was stretched galvanized wire netting with half inch meshes. These circles were arranged so they could be strung upon

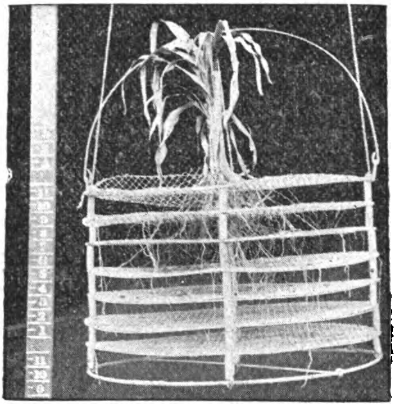


FIG. 11.—Showing the development of corn roots eighteen days after planting.

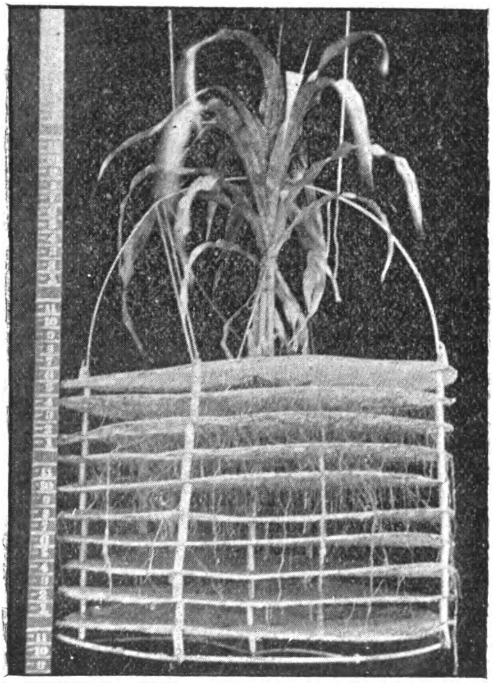


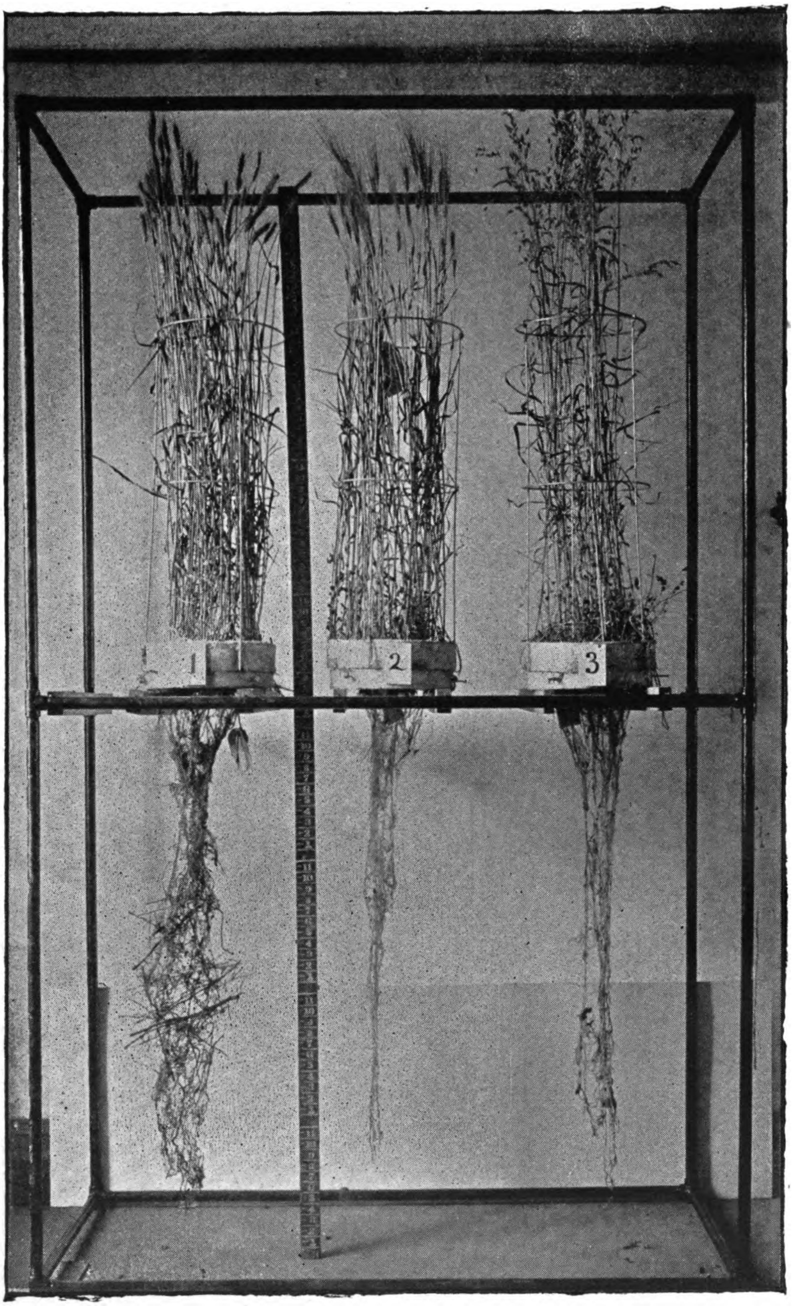
FIG. 12,—Showing the development of corn roots 27 days after planting.

three-quarter inch iron rods and held two inches apart by means of spools, as shown in the cuts. Holes were dug in the field of the desired size and depth, and in the bottom of each was placed one of the circles of each set. Upon these was then replaced two inches of the soil which had been removed, and well firmed. A second circle was then strung upon the rods and two inches more of soil added. In this manner the soil was replaced so as to have the circles lying in it each two inches apart. The upper circle was covered with about two inches of soil and in this the corn was planted directly above the center of the upper circle constituting each set.

At the end of nine days the dirt was removed from around the 18 inch cage and with the force pump, as already described, the soil washed away from the roots. At this stage it was found that some of the roots had extended laterally to a distance of 16 inches, and that some had reached a depth of 8 inches. No roots were found above the upper circle at a distance of three inches from the hill, and none above the second circle at a distance of 9 inches. The tips of the longest roots were 6 inches below the surface, and no roots were nearer the surface than 3 inches, at 6 inches from the hill of corn.

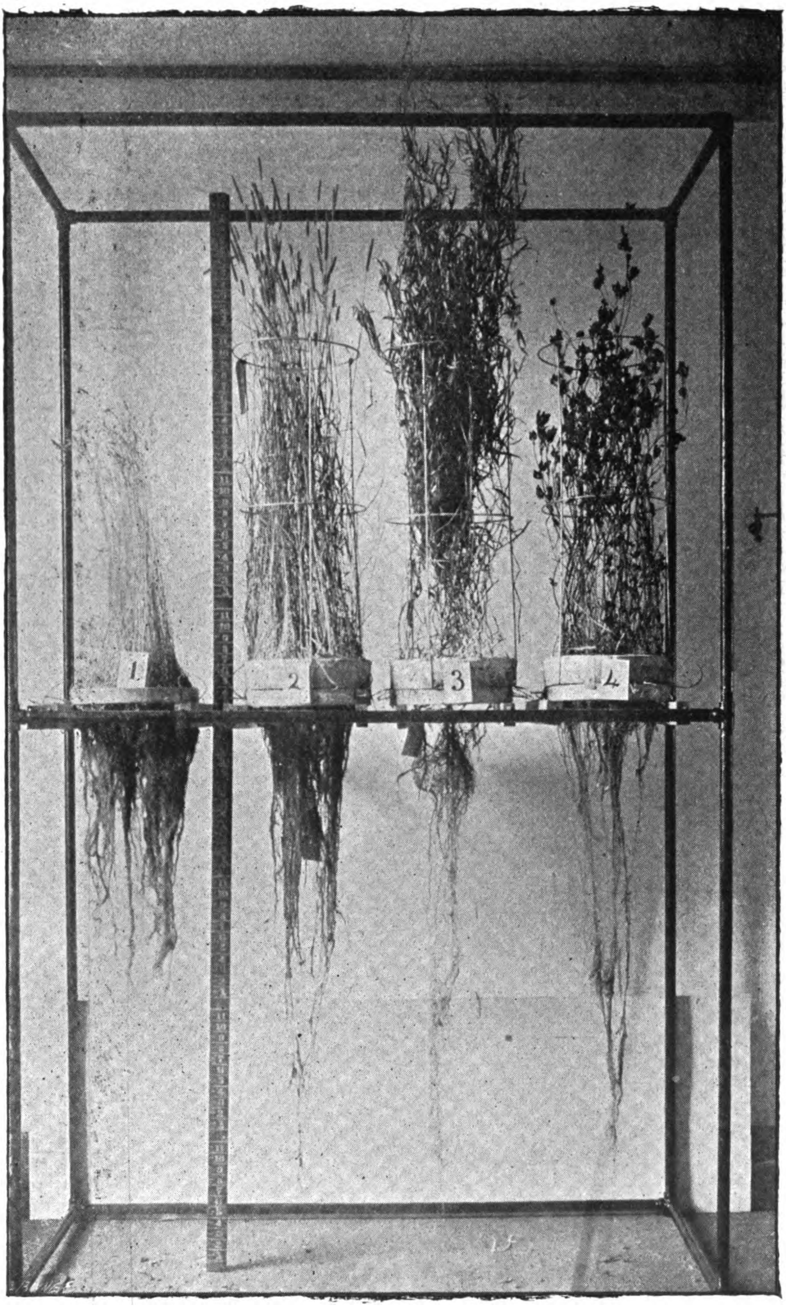
Nine days later, that is, 18 days from planting, the second cage was washed out and is represented in Fig. 11. Here all roots had sunk below the top circle at a distance of five inches, and below the second circle at a distance of 18 inches. The tips of the longest roots had spread laterally to a distance of 18 inches and were 5 or more inches below the surface. The longest roots extending downward had scarcely reached 12 inches. No roots were nearer the surface than 2 inches at 6 inches from the hill.

The roots of the remaining sample were washed out 27 days after planting, and are shown in Fig. 12. Here all roots were below the upper circle at a distance of 3 inches from the center, and below the second circle at a distance of 16 inches. The greatest depth to which the roots had reached was 18 inches, and the longest roots extending sidewise had reached 24 inches from the hill and their tips



1. Wheat. 2. Barley. 3. Oats.

FIG. 13.—Showing the vertical distribution of roots under natural field conditions.



1. Blue Grass. 2. Timothy. 3. *Lathyrus sylvestris.* 4. Clover.

FIG. 14.—Showing the vertical distribution of roots under natural field conditions.

lay 4 inches below the surface. At 6 inches from the hill, no roots were nearer the surface than 2 inches.

III. THE VERTICAL DISTRIBUTION OF ROOTS IN FIELD SOILS.

To procure samples illustrating the vertical distribution of roots in field soils the following method was used:

A galvanized iron cylinder 12 inches in diameter and four feet long was provided, with a stiff outside collar at its upper end to enable it to retain its form while being driven, and an inside collar at the lower end so as to cut a core of soil a little smaller than the cylinder. The sides of this cylinder were perforated with series of one and one-quarter inch holes, through which water could be forced with the pump to wash out the soil from the roots. In obtaining the sample the cylinder was driven down vertically into the soil with a sledge, by striking upon a heavy block of wood placed upon the top of the cylinder. After being forced into the ground in this manner to a depth of 6 to 8 inches, dirt was removed from around the cylinder to within an inch of its lower end, when it was forced down again; this was repeated until the cylinder was forced its full length into the ground, when it was lifted out, carrying all of the soil and roots with it. Two grain sacks were now drawn over the cylinder from opposite ends and the whole immersed in the lake and left from 12 to 24 hours for the soil to soften, thus enabling it to wash out more readily, under the jet from the force pump.

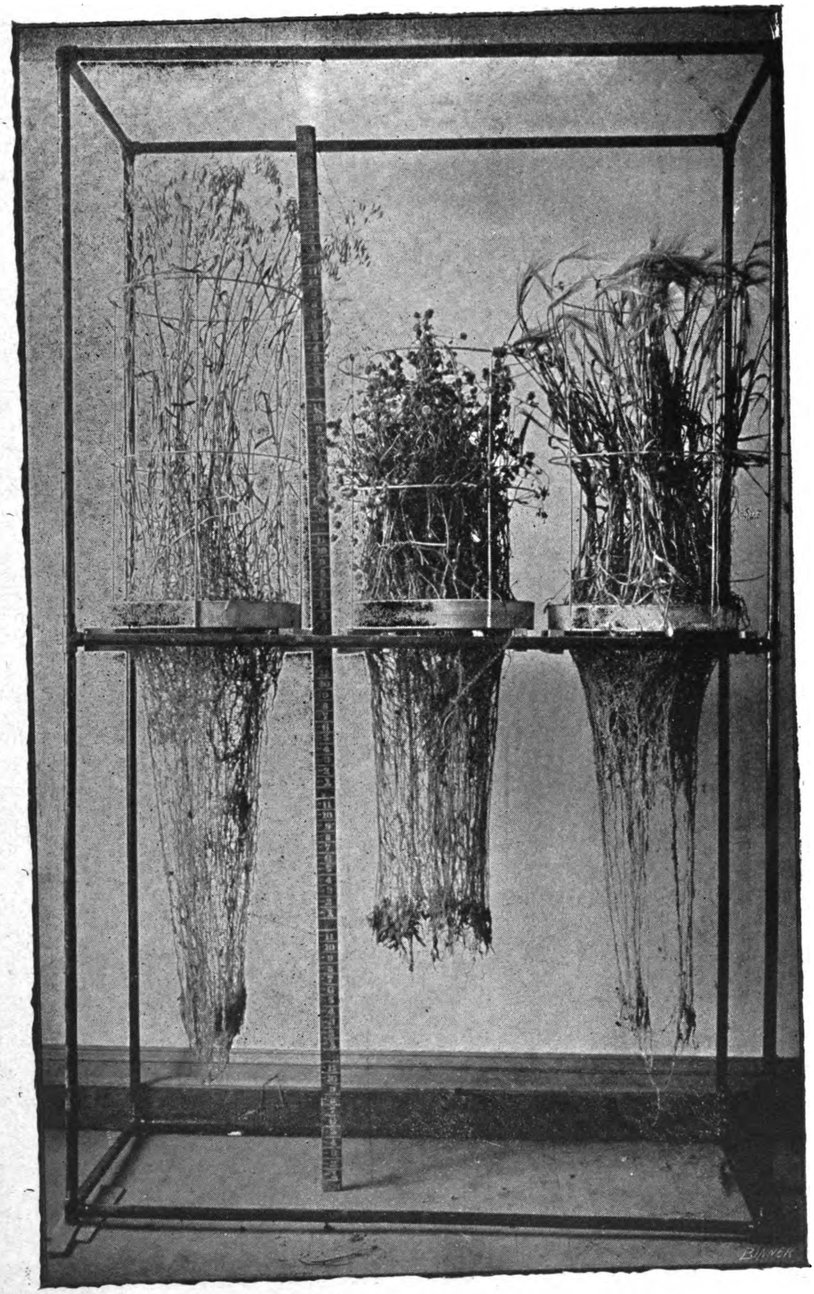
In this manner samples were taken of blue grass, timothy, clover, winter wheat, barley, oats, and the English forage plant, *Lathyrus sylvestris*, and photo-engravings of these are shown in Figs. 13 and 14. It should be noted that with this method of procuring the roots, only those extending directly down from the tops were secured; those which may have extended laterally from these tops were of course cut off by the cylinder, and any which may have come into the cylinder from plants outside would largely fall out with the soil in washing. Only the roots, therefore, which grew vertically downward within a circle whose diameter is one foot, are all that were obtained, and all that are shown in the cuts.

The clover, blue grass, oats, and barley grew in clay loam some 8 in. deep, underlaid by a rather stiff clay sub-soil, 2.5 feet thick which in turn rested upon a rather coarse yellow sand, and the land was tile drained at a depth of four feet. The timothy, winter wheat and *Lathyrus sylvestris* grew upon higher ground in rather heavier soil, underlaid with a firm reddish clay sub-soil containing some gravel. It will be observed that the blue grass has much the shortest roots, being only about 26 in. long, while in each of the other cases a length of nearly or quite four feet is attained. The coarse sticks seen entangled among the roots of the winter wheat are live roots of the black oak, which came from a tree standing thirty-four feet away, in a pasture adjoining the wheat field, and serve to show how far, how deeply and in what a net work the roots of this tree permeate the soil.

In these samples, except the blue grass and timothy, the larger part of the side branches or fine rootlets have broken away leaving only the main trunk lines, and these have been drawn and matted together by the water so as to form an unnaturally slender mass. In the soil they extended vertically downward and filled the whole circle shown by the tops, but it was found impracticable to keep them separate and true to life in this particular

IV. THE TOTAL ROOT DEVELOPMENT OF OATS, BARLEY, CORN AND CLOVER.

As a part of the experiments which have been described aiming to determine the amount of water required to produce one pound of dry matter, an effort was also made to determine the amount of dry matter stored up in the root, and also to preserve specimens showing the total root development which was associated with a given amount of top. To determine the amount of dry matter stored in the root as compared with the top, and to procure specimens showing the amount of root which produced a given amount of top, the soil was very carefully washed away



Oats. Clover. Barley.

FIG. 15.—Showing the total root development of cats, clover and barley

FIG. 16.—Showing the total root of four stalks of corn.

from the roots of the several crops which have been grown in cylinders as described on page 113 of this report, and the photo engraving, Fig. 15 shows the roots of barley, oats and clover thus obtained together with the tops which grew upon them. The cylinder in which the clover was grown was 30 in. deep, and about 10 in. shorter than that in which the oats and barley were grown; this explains the difference in length shown.

The roots and tops of the duplicate specimens which were grown side by side with those shown in the engraving were carefully separated and dried at 212 deg. F. The amount of dry matter in the root calculated per acre, and the ratio of root to top are given below, the stubble, cut close to the ground, being included with the roots:

	DRY MATTER PER ACRE.		RATIO OF TOP TO ROOT.		
	In tops.	In roots.	Tops.		Roots.
	lbs.	lbs.			
Oats	8189.28	3658.17	2.23	to	1
Barley	14196.	4207.9	3.34	to	1
Clover	12486.25	3120.56	4.	to	1

The entire root growth associated with four stalks of corn is represented by the photo-engraving Fig. 15, and Fig 16 shows the conditions under which these roots grew. The total amount of water withdrawn from the soil, including surface evaporation, and used by the four stalks of corn was 300.45 lbs., or the equivalent of 19.6 in. of water on the level. When so much water as this is demanded it is not strange that such an enormous root surface as the sample in question presents should be found. In a duplicate cylinder in which corn was grown the yield of dry matter per acre was at the rate of 19845 lbs. to the acre in the stalks, and 2901 lbs. in the root and stubble close to the ground, making the ratio 6.84 lbs. of top to 1 lb. of root.

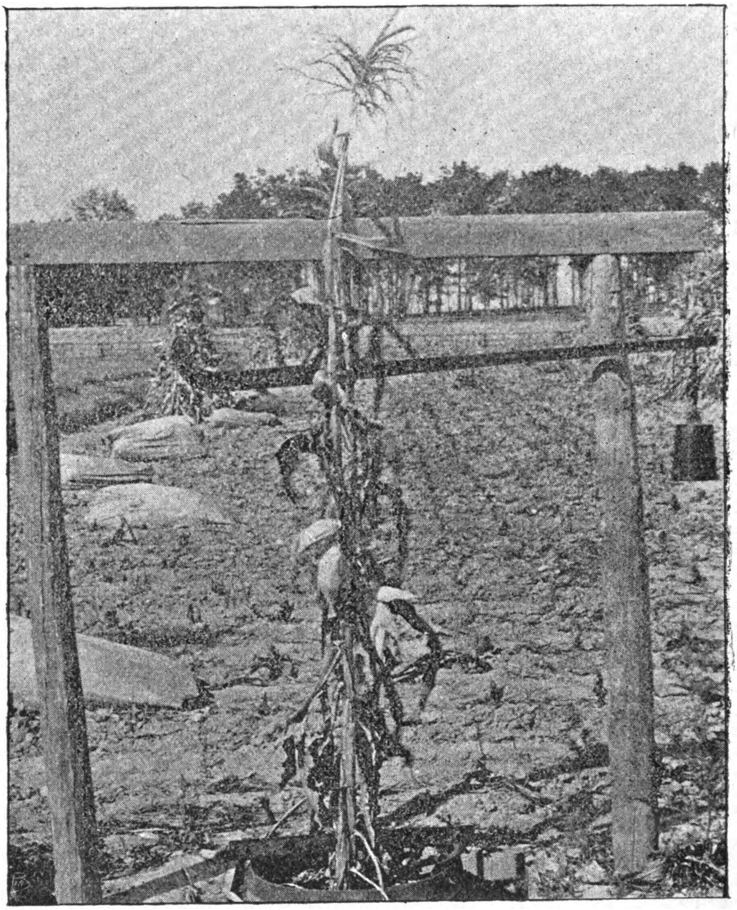


FIG. 17.—Showing the conditions under which the corn roots in Fig. 16 were grown.

It may well be doubted whether the ratios here given will represent very closely those which would be found in natural field soils. However this may be, it must be very evident from all of the samples of roots illustrated in this report, that the aggregate amount of organic matter left in the soil by the crops here considered must be large.

THE CONSTRUCTION AND FILLING OF A ROUND SILO 16 FEET OUTSIDE DIAMETER AND 27 FEET DEEP. CAPACITY 80 TON.

F. H. KING.

The present season a small round silo, having a capacity of 80 tons was built at the station and filled with well matured Litch dent, a strain of Pride of the North. The silo was built as a separate structure and is shown in the photo-engraving Fig. .

CONSTRUCTION OF THE SILO.

The silo has as a foundation a stone wall three feet high and 18 inches thick, laid in Louisville cement and plastered on the inside with two coats. On the inside the upper eight inches of the wall are beveled back as represented in Fig. 18. In laying the wall to a true circle a stake was set in the center, and a board, the length of the radius having a hole bored in one end so as to allow it to slide freely up and down was used in starting the wall at the bottom and in finishing it at the top.

The sill was a single 2x4 cut beveled on the radius of the circle in 2 foot lengths and toe-nailed together after being laid upon the wall, then bedded in mortar. It might also be made without cutting the 2x4's quite in two by making saw cuts every two feet reaching to within one-half or three-fourths of an inch of one side and then springing to the circle and nailing together on the cut side.

For studding 2x4's were used placed one foot apart, and to avoid the extra price for long lengths twelve and fourteen foot pieces were lapped two feet and spiked together before

setting in place. To stay the studding until the siding could be commenced a fence post was set firmly in the ground in the center of the silo. A stud was then toe-nailed in place, plumbed and stayed with a board tacked to the post close to the ground. A second and third stud, each two feet apart were secured in the same manner keeping the inner ends of the stay boards as low down on the center post as .possible. To hold the studding plumb sidewise, strips of half-inch lining about three inches wide were bent around the outside and tacked to the studs as they were brought into the vertical position from side to side. After every altermate piece of studding was fixed in this manner the intermediate ones were set up, toe nailed and tacked to the bands sprung around the outside after being plumbed.

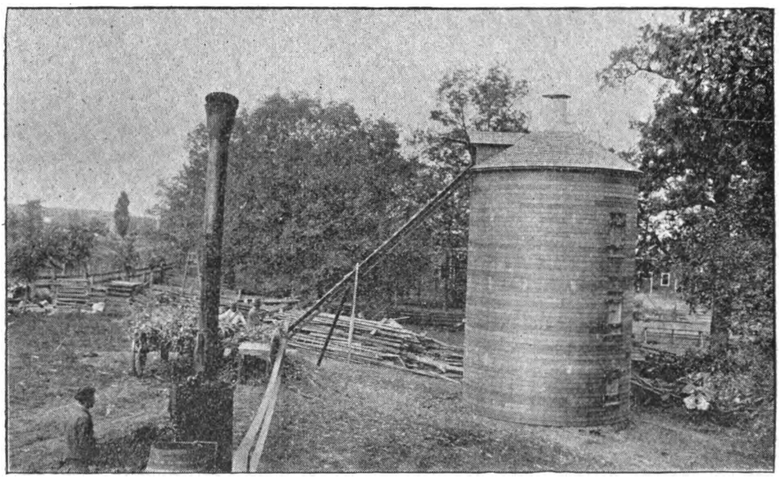


FIG. 18.--Showing an 80-ton silo, 16 feet outside diameter and 27 feet deep.

For lining and for sheeting outside, 6 inch fencing was split in two making it little less than one half inch thick. When the lumber came to be put in place, especially the inside lining, we found it would have been much better to have had the lumber all brought to one width before being sawed. As it was, some pieces were wider than others, and very often the two ends of the same piece were not of the

same width so that some difficulty was experienced on account of these irregularities in keeping the courses horizontal.

When the studding was in place the sheeting was begun on the outside at the bottom and carried up until a staging was required. Care should be taken in putting on the sheeting, siding and lining, to break joints, and it is best to do so in a perfectly regular way by starting the second course of boards one stud beyond the starting point, the third course two studs beyond, and so on.

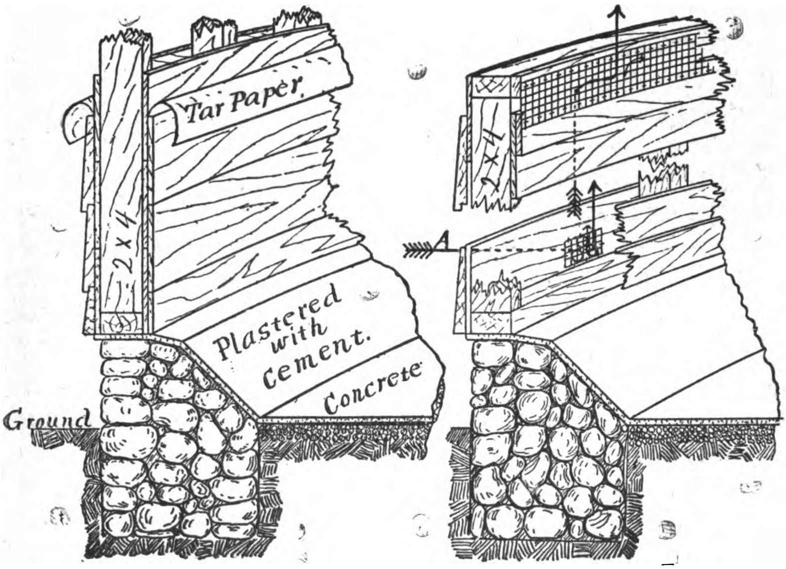


FIG. 19.- Showing the construction of all-wood round silo. Sills 2x4's cut in sections on a radius of the silo circle, bedded in mortar and toe-nailed together. Plates the same, spiked to top of studding. Studding 2x4's one foot apart. Short lengths may be used, lapped, to get the depth. 16's and 14's will give a silo 30 feet deep. Lining made from fencing ripped in two. Outside sheeting the same. Siding for silos under 30 feet, outside diameter, common siding rabbeted; for silos more than 28 feet, outside diameter, common drop siding or ship lap may be used. A, shows ventilators between studding. Auger holes are bored at bottom between studding, and the boards lack two inches of reaching plate at top, inside. Both sets of openings are covered with wire cloth to keep out vermin. There should be a line of feeding doors from top to bottom, each 2 or 3 feet by 5 feet, and about 2.5 feet apart.

The siding was begun before the first staging was put up and the two layers were carried up together to save staging. Ordinary half-inch beveled siding was used, rabbeted as shown in Fig. 19 and it is impossible to put it on unless it is rabbeted. In putting on the first course of siding, lining and sheeting as well, start perfectly horozontal, otherwise the boards will not bend to place readily.

The plate, like the sill, was made by cutting 2x4's in two foot sections and spiking these down upon the tops of the studding after the sheeting and siding had been carried up and the last staging built.

The roof was built without rafters by having a circle made by sawing pieces of 2x8's to the curve of a circle five feet in diameter and spiking two layers of these together breaking joints so as to form a circle. This was supported in place so as to give about one-quarter pitch to the roof and then the roof boards were nailed one end to this circle and the other to the plate. The roof boards consisted of fencing cut the desired length and sawed diagonally from within one inch of one corner to within the same distance of the opposite corner, thus making one end wider than the other.

The shingles were laid to a line drawn by a nail placed in a strip of board which turned upon a center fixed at the peak of the roof, and the cupola or ventilator, was made of galvanized iron and nailed to the roof after the shingling was done.

The engraving shows how the fillIng window is placed. This should have a height of about 3.5 feet and a width of three feet so as to allow a man to pass out and in at one side of the carrier when in place.

The lining of this silo was made of three layers of half-inch lumber, with two layers of tar paper between. The three layers were used because I have feared that two layers of thin siding with one layer of paper between would not permanently give sufficient protection to insure perfect silage in contact with the wall.

The feeding doors should be about two feet wide and four feet high. The studding should be set with reference to the the doors at the beginning, putting two studs together for the sides of the line of doors. An intermediate stud should also be set, and it is best to side and line without reference to doors, cutting them out subsequently.

The doors themselves are best made of three layers of seven-eighths four inch matched flooring nailed to two cleats sawed so as to have the curvature of the silo wall

and of such a thickness that with two layers of boards, with paper between on the inside and one layer on the outside the thickness will be the same as that of the silo wall.

The two sides of the door must of course be beveled because the studs are set so as to face the center and the inner corner of the swinging edge of the door, must be rounded a little to permit it to open and close readily. To fasten the doors shut a pair of carriage bolts are put through the studding opposite the ends of the cleats in the door and strips of band iron 2 in. wide by one-quarter thick bolted to the door along each cleat and provided with a long hole which shuts over the bolt in the studding when the door is closed. This done the doors are held shut by handle nuts like those used on the rods for the end boards of lumber wagons.

The ventilation of the back of the lining between each pair of studs should be secured by boring two inch holes through the siding and sheeting at the bottom and covering these with wire netting on the inside before the lining is put on so as to keep out vermin. One hole between each pair of studs is sufficient. On the inside the lining should not quite reach the plate so that there may be a free draught of air between each pair of studs to keep the lumber dry. During freezing weather the lower openings may be closed in any convenient manner for greater warmth. The openings at the top should be guarded with wire netting to prevent silage from falling in behind as shown in Fig. 19.

Bill of Materials for the Silo.

57 2x4's 12 ft long,
57 2x4's 14 ft. long,
2500 ft. fencing 16 ft. sized and split for sheeting and lining,
820 ft. fencing 16 ft. cut 8 ft. and sawed diagonally for roof boards,
720 ft. siding rabbeted,
120 ft. flooring,
3 M. cedar shingles,
1 circle frame for roof,
500 lbs. tar paper,
7 barrels Louisville cement,
2 ¼ cord of stone,
1 keg of 10 d wire nails,
3 kegs of 8 d wire nails.
1 keg of 20 d wire nails,

50 lbs. 6 d wire nails,
25 lbs. 4 d wire nails.
3 pair 6 in. T hinges.
1 pair 4 in. T hinges,
1 hook and staple,
12 ½ in. x 7 carriage bolts,
6 3-8 in x 7 carriage bolts,
Galvanized iron cupola,
27 lbs. band iron for door fasteners,

Cost of materials	$175 99
Mason labor	29.14
Carpenter labor	42.89
Total	$248.02

The extra layer of boards and paper in the silo lining has increased the cost about $25.00, but the silo has yet to be painted.

COST OF OTHER SILOS.

Mr. C. O. Ruste, of Barber, Wis., built in 1892 a round silo 20 ft. outside diameter, 30 feet deep with 10 feet of stone work in the ground and 20 feet studding above. It is lined and sheeted with split fencing, two layers and paper between inside and one layer with beveled siding outside and 2x4 studding. He states the cost to be as follows:

Lumber	$125.00
Hardware	12.00
5 barrels cement	7.00
30 bu. lime	7.00
30 days carpenter	45.00
Mason labor	30.00
Cash outlay	$226.00

His own labor and teams each at $1.00 per day.

Digging for lower part	$16.00
Hauling sand and lumber	13.00
Quarrying and hauling rock	23.00
Hauling lime and cement	2.00
Making mortar	8.00
Help on carpentery	20.00
Filling around walls, etc	7.00
Home labor	$ 89.00
Total, not including board	315 000

Mr. E. L. Jones, of Hillside, Wis., who built this year a round silo 20 feet in diameter and 33 ft. deep, the lower three feet being of masonry, writes me as follows:

"The lumber for my silo cost me $195.00. I paid carpenter help $50.00; to mason $5.00; incidentals, nails, hinges,

etc., $25.00. Allowing me $25.00 for hauling, etc., would make the cost about $300.00.

CAPACITY OF THE SMALL, ROUND SILO OF DIFFERENT DEPTHS.

During the filling of the new Station silo the past season, a careful record was kept of the weight of silage and of the depth of it from time to time. We had two objects in view: First, to gain more definite data bearing upon the capacity of silos as influenced by depth, and second, to learn whether the capacity of silos of the *same depth* varies with the diameter. The corn put into this silo had, as indicated by small samples taken from each load during filling, an average of 65.5 per cent. of water. The inside diameter of the silo, above the stone work, is 15 feet, and the cubical contents of the space below the sills is 409.86 cu. ft. On the morning of September 9, one day after putting in 47,189 lbs., the depth was 11.75 ft. and the mean weight per cu. ft. of 24.12 lbs. September 10, a. m., two days after filling began the silage had a depth of 10.5 ft., and an average weight per cu. ft. of 27.19 lbs. September 10, in the afternoon, 16,636 lbs. more put in and the next morning the depth was 13 1-3 ft., with a mean weight of 28.56 lbs. per cu. ft., and the next morning with no more silage added the depth was 12 5-6 ft., and the mean weight per cu. ft., 29.71 lbs.

During the day, September 12, 52,561 lbs. of silage were added, increasing the depth to 23 ft. and leaving the mean weight of silage 29.5 lbs. per cu. ft. The next morning, September 13, the silage had a depth of 22 1-6 ft. and a mean weight of 30.65 lbs. The next morning, 36 hours after last fillling, the depth was 21 ft., and the mean weight of silage 32.41 lbs. per cu. ft

September 15, a. m., 2.5 days after filling the depth was 20 2-3 ft., and the mean weight per cu. ft. 32.95 lbs., and this same morning 27,382 lbs. more silage were added, making a depth of 27 ft. and filling the silo to the top, leaving the mean weight of silage per cubic foot, 30.91 lbs.

On the morning of September 17 the silage had settled to a depth of 25 ft., having then a mean weight of 33.45 lbs.

per cu. ft. Two days later the depth was 24 1-6 ft., and the mean weight per cu. ft. was 34.64 lbs.

For fear of frost the balance of the corn was cut and shocked on September 14, where 27,382 lbs. stood until the next morning and the balance until the morning of September 19, when 10,820 lbs. more were cut in making the total weight put in 77.29 tons. This last corn put in contained only 45.14 per cent. of water, and the 27,382 only 58.51 per cent. instead of 69 per cent., the average for what was cut in before. Had the last two lots of silage been as green as the first the silo would have contained more than 80 tons.

Two days after putting in the last silage the depth was 26 5-6 ft., and the mean weight per cubic ft., 33.45 lbs., and on September 28, nine days after filling, the depth of silage was 25 1-3 ft., and the mean weight per cu. ft., 35 48 lbs.

On April 18, when the surface of silage was 20 5-6 ft. below where it was 2 days after filling, and 19 1-3 ft. below where it was when settling had ceased the mean weight per cu. ft., as found by cutting out and weighing seven cubic feet, was 55 25 lbs. This weight is 3.75 lbs less than the computed weight given for 21 ft. in the last Annual Report, p. 244; and the silo is found by trial to hold 10 tons less than would be computed for it, using the data given in that table. This shortage may indicate that the data given in the table referred to are a little too high, but I believe it is chiefly due to the smaller diameter of the silo, because it would seem that the strong lateral pressure against the sides must tend to prevent the settling, and relatively more the smaller the diameter of the silo.

This experiment indicates that with corn containing 69 per cent. of water at the time of filling a silo 15 ft. inside diameter, and resting upon a stone basement 13 ft. inside diameter and 3 ft. deep, will hold silage when of different depths, as follows:

Capacity of small round silos.

With depth 12 ft. the capacity is	24 to 26 tons.
With depth 14 ft. the capacity is	32 to 34 tons.
With depth 23 ft. the capacity is	53 to 55 tons.
With depth 27 ft. the capacity is	80 to 82 tons.

Fig. 9.—Showing the actual distribution of corn roots between two rows at last cultivation.

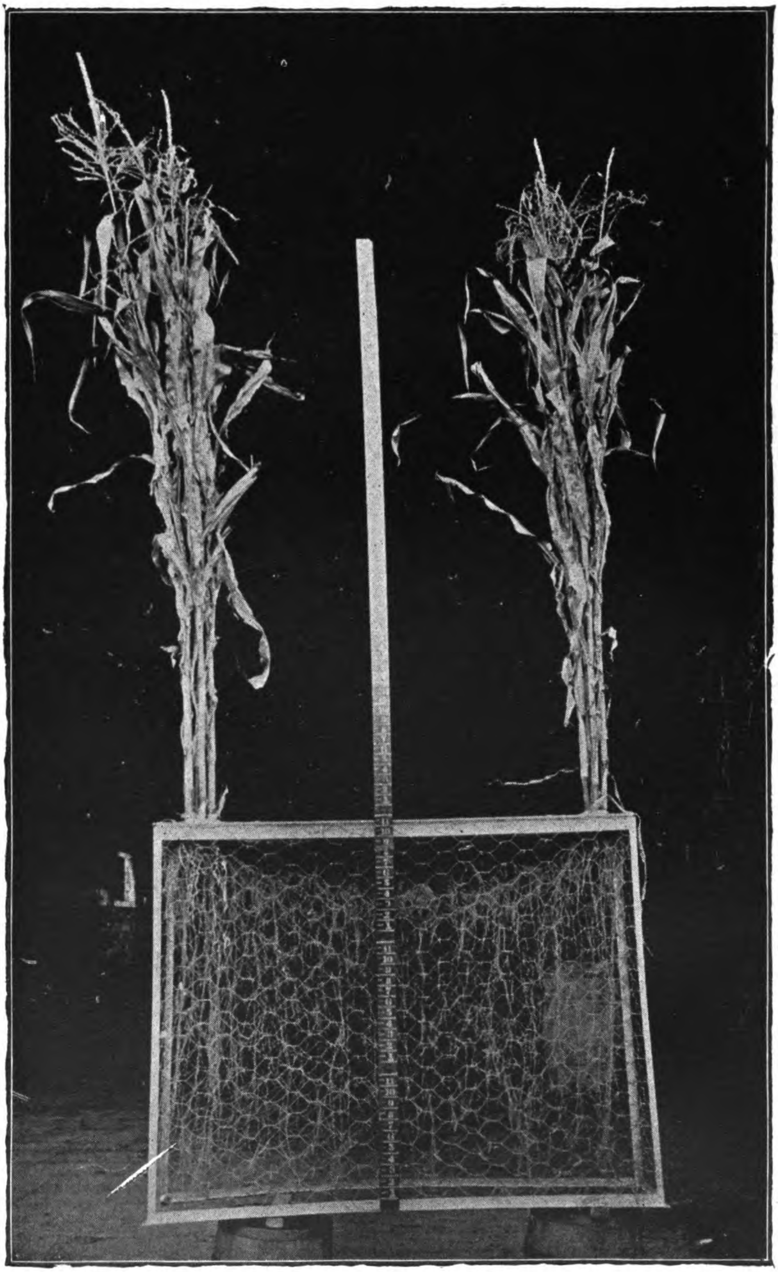


Fig. 10.—Showing the distribution of corn roots between two rows as it is coming into full tassel.

OBSERVATIONS AND EXPERIMENTS ON THE FLUCTUATIONS IN THE LEVEL AND RATE OF MOVEMENT OF GROUND-WATER ON THE EXPERIMENT STATION FARM AND AT WHITEWATER, WIS.

F. H. KING.

The expenses incurred in the conduct of this investigation have been borne conjointly by the United States department of Agriculture, Division Weather Bureau, and this Station, and the article has already been published as Bulletin No. 5 of the Weather Bureau.

FIRST OBSERVATIONS.

When the writer first became associated with the Wisconsin Agricultural Experiment Station in July, 1888, there existed upon the Station farm a double row of silt wells, twenty-four in number, connected with a system of drains. The ground immediately about these wells was seeded to blue grass, and the level of the ground-water had fallen below the level of the discharge pipes in many of these wells, but water still stood in them at distances varying from four to five feet below the surface of the ground. It occurred to the writer, in August of that year, that these wells might possibly furnish an occasion for ascertaining whether the diurnal variations in the rate of evaporation affected, to a measurable extent, through capillarity or root action, the rate of downward retreat of the ground-water surface. Accordingly a record of the height of the water surface in these wells, at 6 to 7 a. m., and 5 to 6 p. m. was kept during about two weeks, from which it appeared that there was a real diurnal change in the water level, the

water in most cases standing higher in the morning than on either the preceding or succeeding evening. That the water should be found lower on the evening following the morning was naturally anticipated on account of the general lowering of the water surface by lateral drainage and the supposed possible lowering by upward flow through the capillarity of the soil and the pumping action of roots; but the general decided rise of the water in the majority of the wells during the night did not appear in accord with fluctuations due directly to the causes named. The surrounding topography and the distribution of vegetation over the surface, at the time the observations were being made, chanced to be such as to suggest that possibly the rise at night might be due to the large consumption of water during the daytime which resulted in depressing the level of ground-water in the locality of observation below the natural slope due to drainage, so that the rise during the night was due to hydrostatic pressure and lateral drainage from the surrounding higher lands or from lands where vegetation was, for the time being, making less demands upon the water in the soil. If this were the true explanation of the large fluctuations observed, it might be expected that those localities where most water was being consumed by vegetation would, other things being similar, show the largest diurnal fluctuations. To test this phase of the question, two other wells were dug, one in a field of growing corn 100 feet to the east of the line of wells in question and the other in a piece of oat stubble the same distance to the westward.

A comparison of the diurnal changes in the water-level of these wells proved that the fluctuations were unequal, being largest in the center of the corn, smallest in the oat stubble, where the least evaporation was to be expected, and intermediate in amount on the margin of the cornfield under the blue grass, which had been cut and was now short. The measured fluctuations, as they occurred in the three wells, are shown graphically in Fig. 20 for six consecutive days, beginning on the morning of September 8, 1888.

While these observations appeared to favor the view that the diurnal fluctuation of the water-level in these wells might be largely, if not wholly, due to a relatively rapid withdrawal of water from the soil by root action during the day, the fact that the water rose in the wells during the night to a height nearly equal to that which it had occupied on the morning of the previous day could not readily be accounted for by supposing that the water surface was warped downward by capillary and root action, because the magnitude of the diurnal changes demanded what would appear to be a much larger consumption of water during the day than the mean rate of lowering of the water level appeared to warrant.

The observations which had been made up to this time showed conclusively that the fluctuations of the ground-water level were really very complex in their character and probably in their origin. It also appeared to the writer that if a ready and accurate means of keeping a record of the fluctuations of the level of standing water in the soil could be devised, new light might be thrown upon the percolation of rain water into soils of different type which lysimeters, from their necessarily limited areas and artificial character, cannot be expected to give. It was hoped also that such observations might be made to throw some light upon the distances below the surface different kinds of vegetation are able to utilize standing water in the ground.

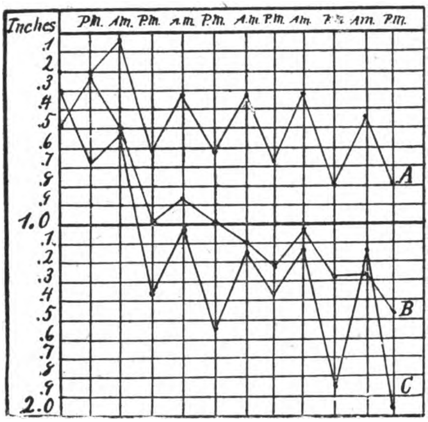


FIG 20.—Diurnal fluctuations in wells: A, on margin of cornfield; B, on oat stubble; C, in corn.

In view of these and other considerations it was decided to dig a number of these wells in localities where the distance from the surface to standing water, the topography, the character of soil and kinds of vegetation vary. Twenty-

one wells were dug which, together with the 25 silt wells already in existence, made 46 in an area about 1,200 feet by 1,000 feet square. The wells vary in depth from 5 feet to 26 feet, and were made by boring with a 7-inch post auger provided with an extension handle. The wells were tubed with 5-inch drainage tile, surmounted, at the surface of the ground, with one length of 8-inch glazed sewer pipe provided with a galvanized iron cover controlled by lock and key.

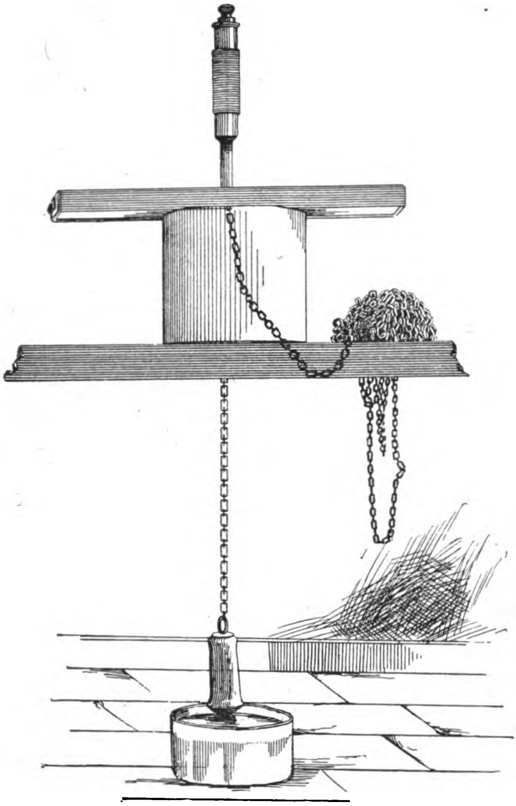


FIG. 21.--Micrometer and chain for measuring changes in the level of water in wells.

INSTRUMENT FOR MEASURING CHANGES IN LEVEL OF WATER IN WELLS.

The instrument used in measuring the changes in the level of ground-water which we shall first consider is represented in Fig. 21, and consists of a chain with numbered

links of uniform length, carrying, at its lower end, a heavy poise and provided with a micrometer at the other, graduated to read thousandths of an inch; this is mounted upon a base which can be placed upon the top of the well and attached to any desired link in the chain.

The essential part of the poise is a hemispherical button of glass one inch in diameter which makes the contact with the water surface. By lowering the poise gradually, until the bottom comes in contact with the water, surface tension, by drawing the water up on the button, develops waves on the water which, by their reflection of light, enable the moment of contact to be readily noted even in 6-inch wells 30 feet deep. Neither a plane nor a conical surface of contact develops such strong waves as does the hemispherical form.

The micrometer consists of a central spindle provided with a hook upon which the chain may be hung. This spindle is moved up or down by a hollow screw which slides over a core graduated to tenths of an inch, and the face of the screw is divided into 100 divisions, which enables distances of one-thousandths of an inch to be read off. With this instrument it has been found possible to measure with certainty changes of level in water less than .03 of an inch.

TOPOGRAPHY OF THE AREA OCCUPIED BY THE WELLS.

The countour map, Fig. 22, will convey some idea of the differences of relief as they exist in the area under consideration. The hill shown in the center of the east side of the contour map rises to the eastward and attains a height of 111 feet above the lake, and then drops down to near the level of Lake Mendota about one mile to the eastward. To the southwest of the map the surface continues to rise nearly 80 feet higher and constitutes a long ridge lying parallel with the one above. The second hill, shown on the east margin of the map, is a small knoll not extending further beyond the boundary of the area mapped than it does into it.

The exact position of all wells within the area under consideration is shown upon the contour map, where they are designated by numbers.

GEOLOGICAL STRUCTURE OF THE LOCALITY.

The experiment station farm, upon which the wells are located, lies just within the terminal moraine of the second glacial epoch, and the glacial till is laid down upon the very unevenly eroded surface of the Madison sandstone. All of the wells of series *A*, *B*, *C* and *D*, lie wholly in the till; wells 48, 49, 50, 51, and 53 pass through the till and penetrate the rock a few feet, while well 52 is said not to have reached rock at a depth of 84 feet, or 36 feet below lake level. Rock was reached in well 53, 16 feet below the lake, and 13 feet in well 48, but in wells 51 and 50 rock was reached 6 feet and 8 feet above the lake level, respectively.

The till is quite heterogeneous in its character, but is much more even at the level of ground-water than above. The whole area is mantled with a stratum of 2.5 feet to 4 feet of reddish clay containing pebbles and bolders irregulary and generally sparsely distributed through it, the pebbles and bowlders being coarser and more numerous on the higher grounds. Beneath this mantle there is generally a rather rapid transition to a sand usually quite uniform and free from gravel everywhere below the 9-foot contour. Beneath the surface of higher levels the transition is into a coarse sandy and gravelly till containing stone 3 to 8 inches in diameter in considerable numbers but usually before water is reached, the coarse materials are greatly decreased or entirely disappear and water is found in a sand of varying degrees of coarseness, it being, as a rule, decidedly finer than that under the lower grounds. Under the higher lands the sand below often approaches quicksand in fineness.

CONFIGURATION OF THE SURFACE OF THE GROUND WATER.

The surface at which standing water is found in the ground is very far from being horizontal, as an inspection of Fig. 23 will show, where the contours are drawn to show the surface of standing water, as observed on June 20, 1892, at the 54 wells included in the area.

It will be observed, in the first place, that the level at which water stands in the wells is everywhere decidedy above the

level of Lake Mendota, to which the contours are referred. Even in well 29, only 150 feet from the lake shore, the water on that date was was found standing 7.2 feet above the lake level. In the well at Agricultural Hall, situated about 3,600 feet east of well 52 on the same ridge, but where the surface of the ground is 88 feet above the lake, the water in the ground stands 52 feet above the level of the lake, and this well is all the way in the till and not over 1,200 feet in a direct line from the shore and not much farther from land near lake level both to the southward and eastward.

A second point to be noted here is the general tendency of the water to stand at the highest level under the highest ground, but there are notable exceptions to this, and more at the particular date which the map represents than has true at former times. Well 52, located upon the highest ground within the area, has yet the lowest recorded water-level excepting those within and near the tile drained section shown in the map. This well, however, is a deep one encased in 84 feet of 6-inch iron tubing which is screw-coupled so as to be water tight except at the bottom. Besides, it was in use during the whole winter, nearly all the water it could supply being taken from it until April 1. After the middle of April it was thrown entirely out of use and so continued until past the middle of May. At the time the measurement was taken the well was in use, but only a few pails of water were taken from it daily. Numbers 53 and 48 are also tubed wells, 52 and 40 feet deep respectively, but were not in use when the levels were taken. All other wells are comparable when account is taken of the fact that the drains, which were still discharging when the levels were taken, would tend to carry the ground water to an abnormally low level in their immediate vicinity.

The real and marked exception to the general rule of the tendency of the ground-water to present a surface approaching conformability with that of the land above is found in well 39, where the water is 16.5 feet above the level of the lake, while that in well 38, less than 60 feet distant, is only half that amount.

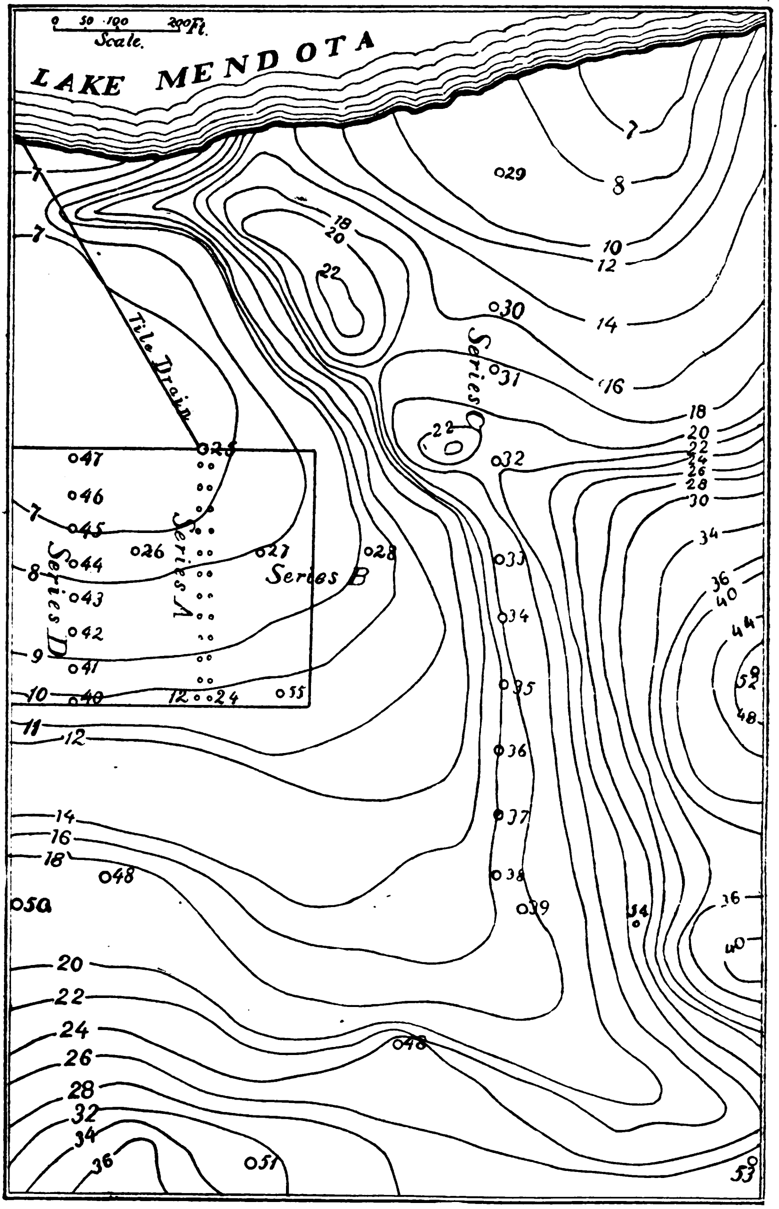


FIG. 22.—Contour map of area occupied by wells. Figures in lines give height of contours above lake in feet; other figures indicate number of wells.

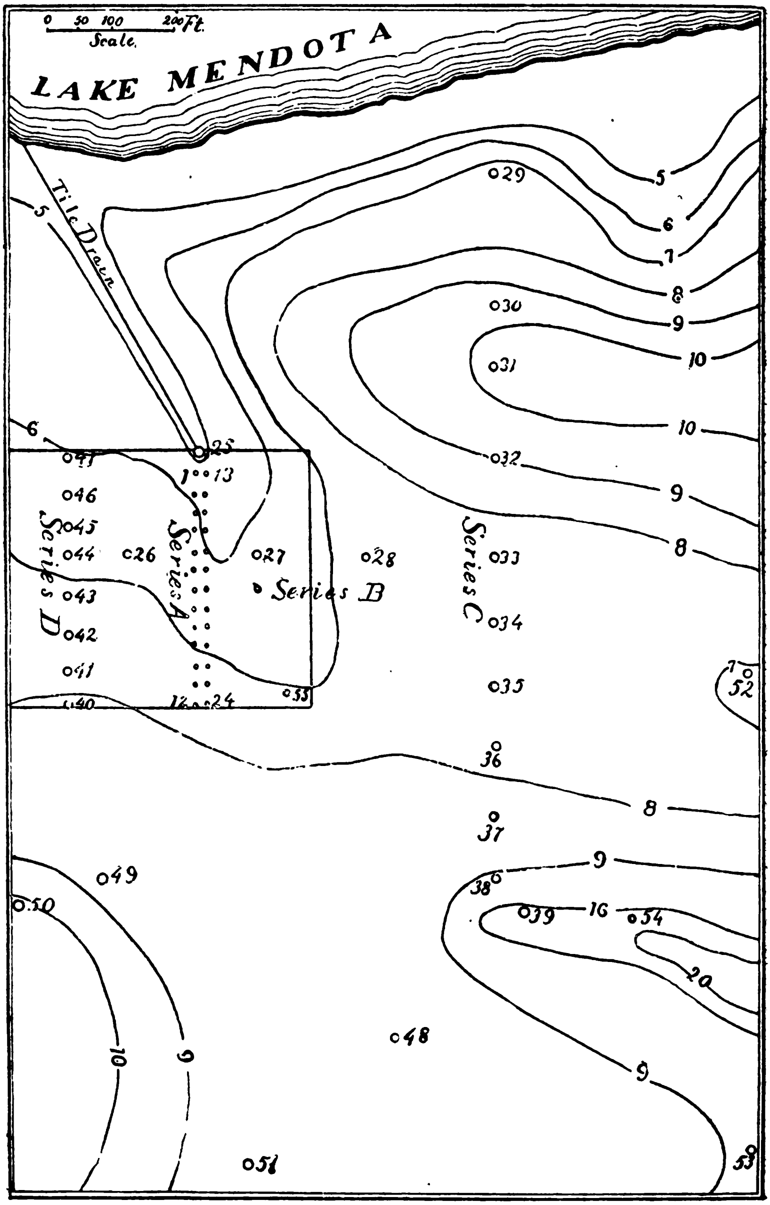


FIG. 23.—Contour map of ground-water surface on June 20, 1892. Figures in lines give height of contours above lake in feet; other figures indicate number of wells.

The rise of the ground-water surface as it recedes from natural drainage outlets, and the resulting tendency to develop a surface unconformable with a true water-level is not a local peculiarity, as has been pointed out by Baldwin Latham*, who expresses the fact as follows:

"The greatest elevation of the subterranean water is usually found under the highest lands, and the least elevation under the lands having the lowest levels. The flow of water laterally is from the hills to the valleys and longitudinally down the valley lines; therefore, as a general rule, the flow of subterranean water conforms to the surface of the country."

THE PERCOLATION OF WATER INTO WELLS.

The measured height of water in a well is not always a true index of the level of ground-water in that vicinity. If the well is in use and considerable quantities of water are being taken from it, the well becomes a drainage outlet toward which the water flows just as soon as the level of the water in it is depressed below that of the general level. The longer such a well is used, when percolation through the soil above does not equal the demand, the more the water-level is depressed below the normal and the wider the area of depressed water level becomes. This causes the water which supplies the well to flow toward it down a continually decreasing slope, and at the same time through soil passageways of ever-increasing length and resistance. Under these conditions, it is evident that a well which is sunk but a few feet below the general level of ground-water would suffer a rapid decrease of capacity during dry seasons, whereas one which is sunk 15 to 20 feet below the natural water-level in the soil would make up in steepness of gradient for the increasing distance from which the water must move toward it from the surrounding soil, as an inspection of Fig. 24 will show.

When the water in the well is lowered to 40 feet below the surface, as shown in the figure, and the water surface

*Report of British Association in 1877, page 207.

becomes depressed so as to conform with the line *a b c*, there is a head or gradient of 1 in 6 tending to force the water into the well, but when the water is lowered to *c*, 30 feet below the general water-level, the gradient becomes 1 foot in 2; but even after long pumping, and the water-level becomes depressed so as to conform with the line *d e f*, the gradient is still steeper than in the first case, being 1 foot in 3 nearly.

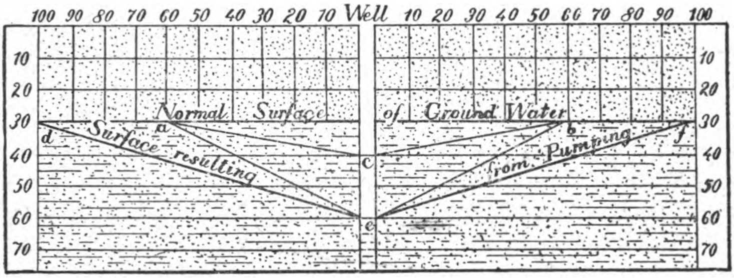


FIG. 24.—Effect of pumping on the ground-water surface.

It is evident, therefore, in providing wells for farm stock there should be an ample depth below the normal level of standing water in the ground, and this must vary with the character of the soil or rock in which the water is stored and through which it must flow to enter the well, the depth required increasing, generally, with the degree of fineness of soil or rock because the resistance to flow increases with the smallness of the particles.

There are times when the height of water in wells is above that of the general level of ground-water in their immediate vicinity, and this occurs during wet seasons after protracted heavy rains and is more marked in clayey soils than in those more open, and more marked in shallow than in deep wells. In the percolation of rain water there is a general tendency for the water to flow laterally toward and accumulate in the wells. This effect is shown very clearly in Fig. 25, which represents the changes in the level of the water in wells, series *C*, whose positions are designated in the two contour maps, Figs. 22 and 23, pages 136 and 137.

These changes occurred after a rainfall of 3.19 inches, distributed in time as follows: June 2, 7:30 a. m. to 9 p. m. 1.38 inch; June 3, 7 a. m. to 2 p. m., .41 inch; 9 p. m., July 3, to 7 a. m., July 4, 1.18 inch; 9:15 p. m., July 4, and again 6:30 a. m , July 5, .22 inch.

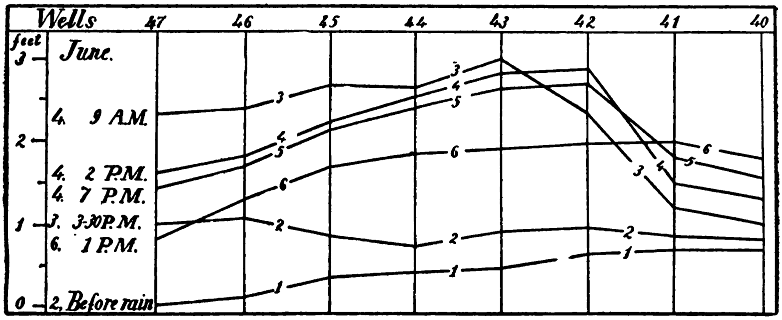


FIG. 25.—Changes in the level of water in wells due to percolation.

It will be seen that a rainfall of 3.19 inches produced a rise of water in well 43 of about 2.5 feet, while in well 40 the rise did not exceed 1 foot. Tne greatest height of water in well 43 was reached on the morning of June 4, while the water in well 47 was still rising slightly 52 hours later, when the water in all the other wells had fallen from .9 foot in well 43 to 1.5 foot in well 47. It is true that the surface of the ground at well 40 is 3.3 feet higher than the surface at well 47, but the chief difference in the amount and rate of rise in the two wells is not due to this fact, neither is it due to water entering the wells at the immediate top, as will be seen from Fig. 26 and the observations stated in connection with it.

All of the special wells used in these investigations are protected at the surface of the ground with a section of glazed tile provided with a lid, as shown in section in the the cut, and it was repeatedly observed during times of rapid and excessive rises of water in the wells due to percolation that the surface of the soil at (*a*) remained dry during the whole interval of percolation, showing conclusively that the water did not enter the wells through the soil at the immediate surface.

The rise of water in wells above the general drainage surface during times of heavy rains is due to the inability

of the soil-air to escape readily upward through the supersaturated surface, for so long as it can not escape it prevents the water from entering the soil spaces occupied by it; wells, however, which are not curbed with impervious tubing furnish an easy avenue of escape for the air, and it is forced out into the wells, allowing the water to follow it, so that there comes to be established, during times of percolation, a movement of water and air in the soil about a well something as represented by the arrows in Fig. 26.

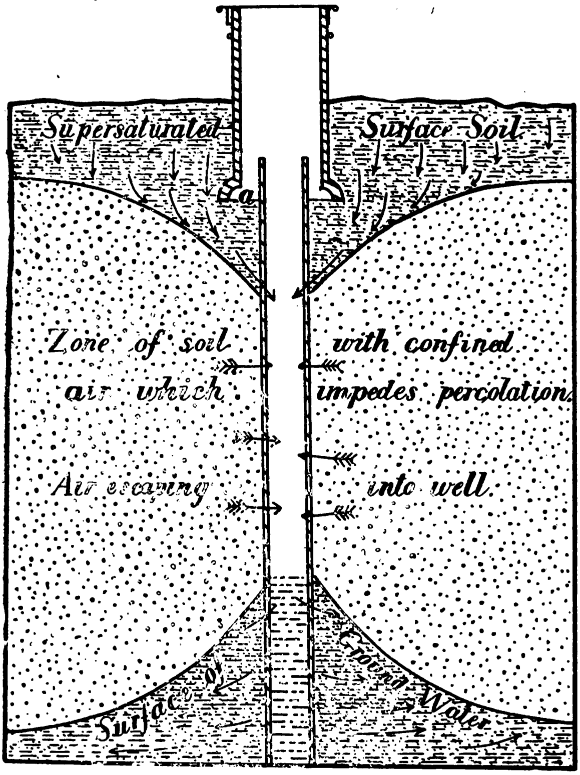


FIG. 26.--Percolation of water into and out of wells.

In the sandy and more open soils, where the interspaces near the surface do not readily become closed with fine sediment moved by the water, there is not as great a lateral flow of water toward the wells, and the water does not rise in them very much more than the general water-level in the ground is raised during such times, and it is because

the soil about wells 47 and 46 is much more sandy and open than it is about the others of this series that there is less rise of water in them at such times. That the lesser rate of rise and amount of it in wells 47 and 46 can not be due to the greater depth of soil through which the water is forced to penetrate is proven by the fact that while in well 28, where the distance from the surface to water at the time was very nearly the same as in well 47, the interval of time before percolation into it became evident was shorter and the amount of rise in it greater even than in well 40.

In trying to fill soil with water, in cylinders a foot in diameter, I have found it practically impossible to do so by adding water to the top, on account of the great difficulty of escape of air laterally or upward. In such cases it has been necessary to introduce the water through the bottom or else put the soil into the water.

That fine textured soils do become almost impervious to air under moderate changes of pressure when they are saturated with water, even in the field under perfectly normal conditions, I have proven repeatedly with a piece of apparatus represented in Fig. 27.

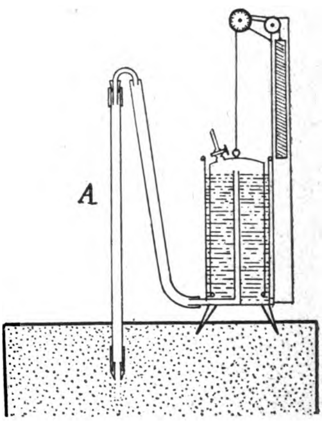


FIG. 27.—Soil aspirator for studying the permeability of soil to air.

In using this apparatus the soil tube, *A*, was forced into the ground to near the desired depth at which the permeability to air was to be tested and then removed and the core of soil turned out. The tube was then returned to its place, and with an auger which would reach a fixed distance below the top of the soil tube, the hole was deepened; then by attaching the aspirator as shown in the figure a definite suction was established and the rate at which the air could be drawn through the soil into the aspirator determined. In this way it was shown that all the surface soils on the station farm are nearly impervious to air immediately after heavy rains and that all the clayey subsoils

are completely so when they are nearly or quite saturated with water. These experiments, however, have not been performed under a greater reduction of pressure than one-tenth of an inch.

Referring now to the contour map of the surface of ground-water it will be observed that well 39, while on rather low ground, has the water standing in it at an abnormally high level, and this is due to the excessive percolation into the well during the present wet season. On the other hand, well 52, which is in the highest ground and yet with a very low water-level, represents the other phase which we have considered, a case where the ground-water has been lowered by excessive pumping.

A SANITARY PROBLEM.

There is a sanitary aspect to this question which should not be overlooked. Well 39 showed, by the rapid fall of a little more than 2 feet which took place in it during less than 10 days following the measurement recorded on the map, that its great height of water was due to lateral percolation into it, and the point to which I wish to direct attention is that we have here a ready means of ascertaining whether a well is subject to surface contamination or not. A sudden large rise and fall of the water-level in a well, associated with heavy rains, can have no other interpretation than that water reaches the well without being filtered through a large amount of soil. An abrupt rise and fall of a few inches might have no significance here, as will be seen from observations recorded in another place, but where there is a rise and fall of a foot or more there can be no doubt but the well is liable to yield, at times, unsanitary water if the surface surroundings are such as to permit of it. The observations here recorded also indicate that wells located in clayey soils and subsoils may be much more subject to such surface contaminations than others in more open and porous ones.

Just how far it is practicable to protect wells which are subject to contamination in this manner, by using iron tubing or other similar impervious curbing, is a matter which merits careful investigation, for it is a vital question in the

building of country homes. It is generally taken for granted that wells thus constructed are safe against the infiltration of surface water, and it may be true to a large extent; but it does not appear improbable, in pumping water from a well tubed up with iron, that the rapid withdrawal of water from about the immediate terminus of the tubing would tend quite as strongly to bring the new supply of water directly downward from above as to induce it to come from below or from lateral directions, and if this is true, it is evident that the surface surroundings of a well used for domestic purposes should be scrupulously cared for even when provided with impervious curbing.

ONE CAUSE OF DECREASE OF HEAD IN ARTESIAN WELLS AND AT PUMPING STATIONS.

It is not an uncommon occurrence for artesian wells to show a decrease of head, which, in many cases, is very appreciable and not apparently caused by seasonal fluctuations of the level of ground-water, and the same fact has been observed at pumping stations also. In my judgment, the observations made in the preceding section offer a partial explanation of these changes; for the opening of an atesian well in an impervious soil through which water has not been discharging must have the effect of depressing the surface of the ground water which contributes to the well, and as the new drainage surface of equilibrium must occupy a lower level it follows that the head must suffer a permanent decrease, and this might be such as to cause certain wells in a locality to cease flowing altogether.

SEASONAL CHANGES IN THE HEIGHT OF GROUND WATER.

The impounding influence of all porous lands lying above drainage levels, causes the ground-water surface to rise during wet seasons while during dry ones it falls so that the effective head in artesian wells and in springs is increased or decreased peridocally in accord with the fluctuations of the yearly rainfall and those other conditions which tend to diminish the amount of water which is able to enter the land. In the same manner, also, the capacity of ordin-

ary wells to supply water varies as the general level of the ground-water rises and falls. The locality under consideration here is one in which the supply of shallow wells must be almost, if not quite, the percolation water of purely local rains.

The wells in series *C*, which are in the higher land of the station farm and most remote from the system of the drains, are best suited to show the long period fluctuations due to the quantitative relationship existing between the amount of rainfall and the rates of drainage and percolation. When the wells were sunk, in August, 1888, there was water in all of them except 31 and 36, and the level of the water in them is shown in Fig. 28, on the stated date in 1888, 1889, 1890, and 1892. During the latter part of the summers of 1889 to 1891, inclusive, all of the wells of this series became dry, except No. 30, which is nearest to the lake, and in each case it has been true that, after going dry, they did not contain water again until after April 1, the following spring.

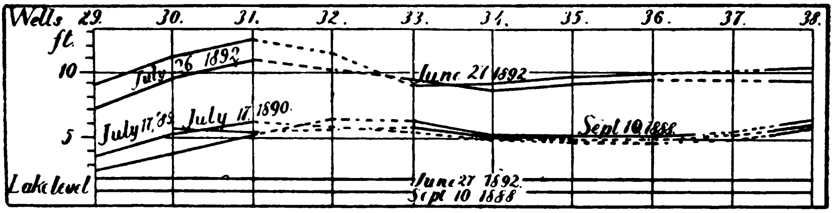


FIG. 28.—Profiles of ground-water surface along the wells of series C.

It will be seen that the surface of ground water in June, 1892, is from 4 to 5 feet higher than at any other season since the records began. The level of Lake Mendota was also higher, but its range has been confined between this level and one almost two feet below.

RELATION BETWEEN THE AMOUNT OF RISE IN THE SURFACE OF GROUND WATER AND THE RAINFALL.

When, in the spring of 1892, the surface of ground-water first began to rise above the level of the bottoms of the wells in series *C*, its contour had approached very close to

horizontality, as shown in Fig. 29, where the profile lines of May 7 and May 21 show the configuration of the surface at these times. Between May 21 and June 7 the arithemetical mean rise of all of the measured wells was 1.5 foot, and the rainfall between those dates was 4.02 inches. Between June 7 and June 27 the mean rise was 2.38 feet, and the rainfall associated with it 4.97 inches. The total mean rise between May 21 and June 27 was 3.88 feet and the rainfall for the same period 9.05 inches. During the first of these periods the water rose .373 foot for each inch of rain; in the second it rose .479 foot, and during the last, .428 foot for the same amount of rain.

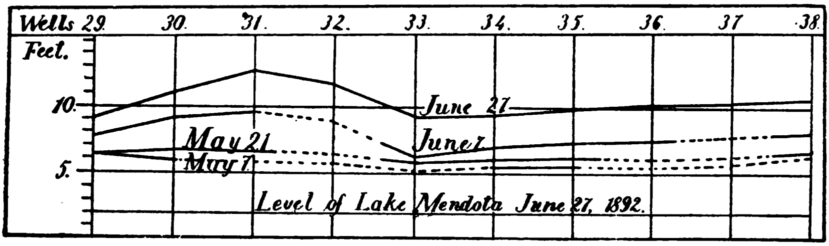


FIG. 29.—Rise of the ground-water in relation to rainfall.

If now we refer to Fig. 24 and take the mean distance between the two lines 1 and 6 as representing the true rise of the ground-water surface due to percolation, we shall have for a rainfall of 3.19 inches a rise of 1.27 foot, or at the rate of .398 foot for each inch of rain. The general mean of all these is about .42 foot of rise in the ground-water for each inch of rain.

Determinations made at this station show that there is about .4 cubic foot of space in one cubic foot of dry sand, and that capillarily saturated sand standing one foot above water, such as the rise here considered took place in, would contain about 18 per cent. of its dry weight of water, while the weight of one cubic foot of such water-free soil is not far from 105 pounds. Under these quantitative relations the capillary water should occupy .32 cubic foot and the unoccupied space into which water could percolate would be only

$$1 \text{ cubic foot} - (.6 + .32) = .08 \text{ cubic foot},$$

or 138.24 cubic inches. Under these conditions an inch of rain should fill a cubic foot of soil more than full; but as the ground water was raised at the mean rate of only about .42 foot it follows that either the soil did not contain 18 per cent. of its dry weight of water at the time the rains occurred or else that there was, during the time, a large amount of percolation through the zone under consideration.

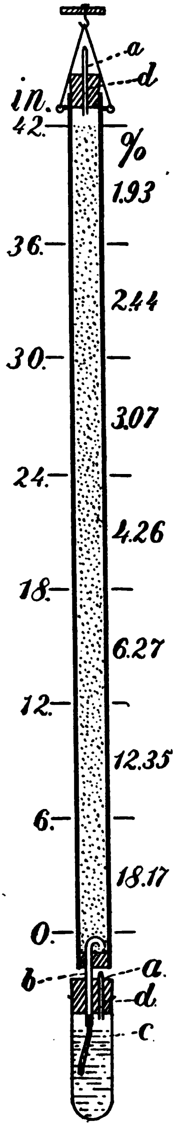


FIG. 30.—Method of determining the distribution of capillary water in long columns of soil.

THE CAPILLARY STORAGE CAPACITY OF LONG COLUMNS OF SOIL.

There is in my own mind no doubt that the soils considered in the last section, into which the water percolated, did not contain 18 per cent. of water at the time under consideration, and my reasons for this conviction are these: In coarse, sandy soils at least, if not in all others, the capillary holding power decreased in some undetermined ratio with the length of the column above standing water, as I have proven by the following experiment: Columns of medium grained plastering sand 42 inches long were constructed and suspended in a vertical position, as represented in Fig. 30. The sand for this experiment was stirred in water to expel all adhering air and then poured into the tubes through a funnel, sand and water together, the tubes being frequently shaken and jarred to insure a solid packing of the sand.

The tubes were hung in place on April 26, 1892, and percolation had not ceased on May 14, although the rate had become very small. At this time 20 cubic centimeters more water was poured into the tubes at the top, when a rapid percolation was set up immediately, but did not cease entirely until some time between June 3 and 10. On June 10 percolation had ceased, as shown by the receptacles having lost in weight

0237 grams to .0036 grams. The tubes were then cut into 6-inch sections, and the water content of the sand determined by placing the sections directly in the dry oven. The tube which had been wet with distilled water possessed the distribution of capillary water indicated in Fig. 30, where it will be seen that there is a decreasing amount as the distance above standing water increases, it being 18.17 per cent. in the lower 6 inches and only 1.93 per cent. in the upper, with a mean of only 6.927 per cent. This difference in distribution was due wholly to percolation, as the nearly constant weight of the whole apparatus proved, that only showing an almost inappreciable loss through evaporation of water from the fine vents in the two corks at the top and the bottom.

It was to me surprising that the percolation was so large and yet toward the close so extremely slow, but results of similar import have been obtained through direct observations upon the soils in their natural positions in the field. In the Seventh Annual Report of this Station, page 144, a record is given of the changes in the water content of the upper 5 feet of soil situated about 70 feet northwest of well 52, Fig. 21, which, during the interval from October 28, 1889, to April 14, 1890, was covered so as to exclude snow and rain, the object being to ascertain whether, during the winter, there was an increase of water in the soil through the aid of capillarity in drawing water up from below. It was there shown that instead of becoming more moist during the winter the water content actually decreased, and to the extent of 1.66 per cent. of the dry weight of the soil in the upper 4.5 feet; the lower six inches alone showing a gain in moisture. This loss of moisture referred to I then attributed to surface evaporation, "and possibly to lateral and downward translocation." Other observations now at hand, but which need not be detailed here, convince me that the chief loss of moisture in this soil during the winter was due to slow percolation downward, and that soils are drained more and more by percolation downward as the surface of the ground water recedes. Judging from the per cent. of water retained by the plastering sand it

would appear that the zone of soil through which the ground water rose during the interval from May 21 to June 27 may not, at the beginning, have contained more water than 6 per cent. of the dry weight of the soil and that it is due to this fact rather than to underground drainage that the surface of standing water in the ground was not carried to a greater height than was observed.

RELATION OF THE NORMAL GRADIENT OF THE GROUND WATER SURFACE TO TILE DRAINAGE.

The prime function of tile drainage is to hold the surface of ground-water at an adequate depth so that there shall be ample room for root development, and as the ground-water rises with each increment of distance from the drainage outlet the proper distance to place the tile apart in a given soil, where they are to be placed at a stated depth, turns upon the resistance which the soil offers to the flow of water through it, for it is this resistance, just as in the flow of water through pipes, which determines, primarily, the steepness of the ground-water surface.

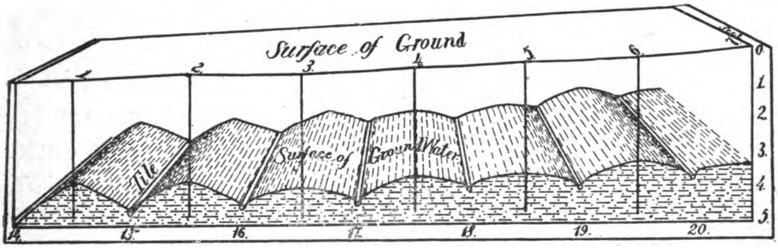


FIG. 31.—Surface of ground water between tile drains 48 hours after a rainfall of .87 inch.

To determine the actual contour of the ground-water surface in a tile drained field when the drains were doing duty, a line of seven wells was sunk midway between the lines of tile which are laid in the area designated on the contour map, Fig. 22. The lines of tile in this field are laid as nearly as may be 33 feet apart and at a distance below the surface of the ground of about 4 feet. The wells referred to were put down midway between the lines of tile, and therefore were situated 16.5 feet from the drains on either side and at at a distance not exceeding 30 feet from the line of silt wells

into which the drains discharge. The soil of this locality consists of 6 to 8 inches of medium clay loam followed by 2.5 to 3 feet of clay, below which is a stratum of rather coarse sand, in the upper surface of which the tiles are usually laid, and in spots this sand contains some gravel. The tiles are 3 inches inside diameter and laid on a grade of about 2 inches in 100 feet. At the time the levels were taken the tiles were discharging less than one-twentieth of heir capacity.

The observed contour of ground-water in this field at 8 a. m., May 13, 48 hours after a rainfall of .87 inches, is represented in Fig. 31. The highest water-level in any well between these lines of tile on this date, when referred to the tops of the tile between which the wells are, was one foot in the case of well 1, above tile 14, and the lowest was about .3 foot in case of well 5 above tile 18. Both wells 5 and 3 were sunk into a sand containing a considerable amount of gravel, and to this fact is probably due the less steep gradient at these places. Between well 2 and tile 16 two other wells were sunk, one two feet from the drain and the other midway between the drain and well 2. In the well 2 feet back from the drain water stood .3 foot above the top of the tile, and in the other, .45 foot above; the profile would present, therefore, a more or less curved contour, convex upward.

Assuming the water-level at the several lines of tile to be flush with the tops of the tile and regarding the water surface as presenting a right line section, the mean gradient for the ground-water surface would be one foot in 25.38 feet. In well 29, 150 feet from the lake shore, the water stood 7.214 feet above the level of the lake on June 27, 1892, and this would give a gradient of one foot in 20.79. In the case of the well at Agricultural Hall to which I have referred as having a water-level 52 feet above the lake, and situated about 1,250 feet from the shore, the mean gradient would be one foot in 24.4. In the fall of 1888, September 10, when the water-level in the well could not have been affected by lateral percolation into it, the gradient between well 29 and the lake was 1 foot in 35.86 feet.

In the tile drained area under consideration the configuration of the water surface did not remain as shown in Fig. 31, but changed as the water was carried away by the drains, and in Fig. 32 is shown the profile of the ground-water on these different dates. The changes which had occurred in the level of the water show that it was not drawn down at a uniform rate at all places, the surface falling fastest under the highest ground where the water level was also highest; also that the hydrostatic pressure of the water was there effective, tending to produce a horizontal movement from the upper toward lower portions of the tile drained area, associated with a downward vertical movement under the higher area, increasing the rate at which the level fell in that place and apparently decreasing it in the lower section by determining an upward tendency of the water from below.

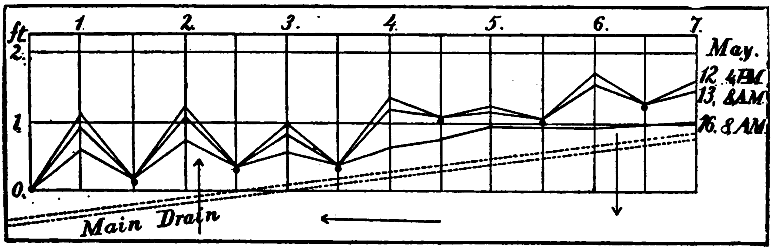


FIG. 32.—Changes in level of water between tile drains.

It is a constant feature in the discharge of water from this system of drains that those tiles laid in the lower ground continue to carry away water months after those under the higher ground have ceased to do so, and as there is no more soil to hold water for the drains to carry away under the low than under the higher ground it follows that there is a tendency for the water to rise up into the zone affected by the lower tiles.

NATURAL SUBIRRIGATION.

It is a fact long established by practical experience that many low lands which require tile draining in order to bring them under cultivation, and lying adjacent to higher areas, become, when so treated, if adequately done, the

most productive lands of the locality, and while there are several conditions which render them so the paramount one is the water supply naturally provided by the upward tendency of it under the lower lands, coming from the supply of impounded water in the soil of the surrounding higher ground in the manner illustrated by the observed changes in the confirmation of the ground-water surface referred to in the last section. The tile drains when properly placed serve during seasons of superabundance of water to hold the water-level below the zone of root action, while during seasons of deficient rainfall they do not interfere with its rise by hydrostatic pressure into the region where it becomes available to the growing crops. This is an important principle to understand in the selection of land for intensive farming.

Not all low land adjacent to high areas are subject, in equal degree, to the natural subirrigation referred to, for geological differences of structure necessarily modify the movement of the rain which has entered the ground or may even prevent it from entering it so as to become available in the manner under consideration. The geological structure best adapted to the storing of water in the high lands and of giving it out gradually to the lower areas adjacent, is represented in Fig. 33, where the surface is mantled to a depth of 3 to 4 feet with clay soil and subsoil. This mantle on the high land passes by degrees through a porous, sandy and gravelly clay into a sand and gravel or pure sand of considerable depth into which the surface water rapidly penetrates, and out of which it flows laterally with comparative ease. Under the hillside this course gravel and open storage material shades into a medium grained or rather fine sand through which the water can flow with some degree of freedom but not so rapidly as to fail to store the water to a considerable height above the surface of the low land. This type of geological structure is that possessed by the tract of land under special consideration here, and is very common throughout wide areas of the United States which are heavily mantled with the deposits of the later glacial epoch. The terminal moraines of this country

are impounding reservoirs of great extent and capacity into which the rain sinks immediately and is there stored under conditions of least possible loss by evaporation, to be given out gradually in restricted but innumerable areas. Heavy rains which in differently constituted sections are lost to agriculture in disastrous floods are here safely and economically stored. It is to this stored water escaping slowly from the ground again, more than to direct rainfall and flat topography that we owe the existence of our innumerable small lakes and the many acres of swamp and lowland pastures so characteristic of glaciated areas, and it is to these many natural subirrigated tracts which I wish to call attention, as being so promising for the purposes of market gardening and other types of intensive farming.

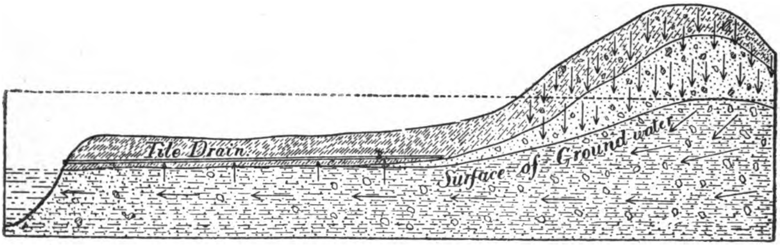


FIG. 33.—Geological structure favorable to natural subirrigation.

There is another point in this connection to which attention should be called. There are numerous tracts of country underlaid by artesian waters, at varying depths, and where it is only necessary to penetrate the overlying impervious strata to obtain water at the surface. Now, it is a well established fact that the very best Portland cements are very far from being wholly impervious to water even under moderate pressure, and in view of this fact it has often occurred to me that a careful study of the yield of crops per acre for years of deficient rainfall, in artesian districts as compared with that of adjacent areas which are not, might reveal the fact that there is a not inconsiderable supply of water from below; which might help to explain the peculiar productiveness of certain sections.

This question is not without significance in its bearing upon the supply of water to cities through the instrumen-

tality of artesian wells, because if it is true that there is a slow but general drainage of artesian basins upward through the confining strata, one effect of this drainage might well be to develop an increasing porosity of the confining beds which would diminish the effective heads of the wells and might, in time, even cause them to cease to flow altogether, not from a diminished rainfall, but by a diversion to agricultural uses through a general subirrigation of the waters which had been or are being uesd for city purposes.

It does not appear impossible either, that in districts not underlaid by artesian water, there might be a general lowering of the water in the wells of the higher grounds on account of an increasing porosity of the soils of the surrounding lower lands.

FLOW OF GROUND-WATER FROM THE LOWER UNDER THE HIGHER LANDS.

When a series of dry years have occurred, like the three just past, the surface of ground water is drawn down to an abnormally low level, as was the case on May 7, shown in Fig. 29. Then when such a period is followed by heavy rains the soils of the low lands frequently become filled first so that the normal configuration of the water surface is reversed, that under the low lands not infrequently standing higher than that under the higher areas. The reasons for this reversal are two, first, the low lands have less storage capacity than the high on account of there being less depth of soil, and second, not all the rains which fall upon the high lands can remain upon the surface long enough to enter the soil, and, as a result, the low lands not only receive practically the same amount of rainfall but a portion of that which falls upon the hills is carried, by surface drainage, down upon them, and in this manner the ground-water level may be carried several feet above that under adjacent higher lands. Referring to Figs. 28 and 29, and to the two contour maps, Figs. 21 and 22, it will

be seen that in September, 1888, the water-level at well 33 is higher than at any other point, whereas on June 27, 1892, the water there has a lower level than at any other point along that line of wells. Under these conditions there is a reversal of the direction of the underground movement of the soil water, the current setting from the low areas toward the higher lands, and by this reversal there is restored to the high lands a portion of the water which fell upon them as rain after it had flowed down upon and percolated into the bordering lower grounds. Well 33 has been, and is at this date, July 18, still rising, while the water in the other wells is falling.

THE RATE AT WHICH THE LEVEL OF THE GROUND-WATER SURFACE CHANGES.

The mean rate at which the ground-water surface rises and falls has varied between rather wide limits, but, as a general rule, a much shorter period has been required to produce a given rise than has been consumed in producing an equal change downward.

In Plate I, I have plotted the twice-daily observations on wells of series *B* and *D*, extending over 100 days beginning June 8, 1889, and ending September 17. At the beginning of these observations the surface of the ground-water was already below the level of most of the tiles so that the lowering of the surface could not be influenced directly by the action of the drains. The total mean fall of the ground-water surface for wells 40 to 46, and 27 and 28 was 13.95 inches during the 80 days from June 18 to September 6, or a mean daily rate of .174 inches. During 131 days, from May 27 to October 29, the total mean fall was 20.495 inches with a mean daily rate of .156 inch for wells 40 to 46. During 112 days, from June 9 to October 7, 1890, the total mean fall for the same wells was 20.086 inches, or a mean daily rate of .179 inch.

An inspection of the chart shows that the different wells did not all fall at a uniform rate, and if we arrange them

in the order of the distance of standing water in the ground below the surface we shall have—

	Inches.
Well 46 fell during 80 days	13.2
Well 47 fell during 80 days	12.1
Well 45 fell during 80 days	12.9
Well 44 fell during 80 days	13.25
Well 48 fell during 80 days	13.3
Well 43 fell during 80 days	13.8
Well 42 fell during 80 days	15.0
Well 41 fell during 80 days	15.4
Well 40 fell during 80 days	16 6

With but one exception, that of well 45 as compared with 46, the water fell more rapidly in the shallow than in the deep wells. The more rapid fall of the ground-water under the lower land was due to two causes, first, the shorter distance to the drainage outlet at the lake making the resistance to the flow less, and, second, to a more rapid loss of water at the surface of the ground through combined capillary and root action.

To ascertain whether corn exerts a measurable influence in depressing the ground-water surface, the ground occupied by the wells of series *D* was divided transversely into as many plots as there are wells, and in 1889 corn was planted over wells 40, 42, 44 and 46, while the ground above wells 41, 43, 45 and 47 was left fallow; then in 1890 the conditions were reversed. Determining the mean fall of water on the fallow plots and comparing this with the mean fall observed on the corn plots for the two years, we get the results given in the table below:

Table showing mean fall of water on corn ground compared with that on the fallow ground.

Date.	Corn.	Fallow.	Difference.
1889.	*Inches.*	*Inches.*	*Inch.*
May 27 to June 20	1.973	1.918	.055
May 27 to July 1	3 516	3.156	.360
May 27 to July 10	5.442	5.091	.351
May 27 to August 1	8.585	8.353	.232
May 27 to August 24	12.088	11 978	.110
May 27 to September 26	15.443	15.324	.119
May 27 to October 29	20.573	20.416	.157
1890.			
June 19 to July 2	2.914	2.646	.268
June 19 to July 10	7.248	6.965	.283
June 19 to August 1	13.532	13 359	.173
June 19 to August 28	17.456	17.052	.404
June 19 to September 27	19.872	19.485	.387
June 19 to October 7	20.288	19.881	.404

It will be here seen that during the whole of the growing season the mean fall of the water under the corn plots was greater than it was under the fallow ones, not simply in 1889, but also in 1890, when the plots were reversed. It would appear, therefore, so far as two concordant trials can prove a complex problem, of this character, that corn does exert a measurable influence in depressing the surface of standing water in the ground where it lies at the distance below the surface which it occupied in these trials, which was 7.77 feet at well 40 in 1889, on September 26, when the corn was cut. During the season of 1890, after the June rains, the water was raised about 1 foot above the level of the preceding year at this date, and this difference was maintained throughout the growing season, and associated with this higher level of ground-water there was a larger difference between the levels of the water under the fallow plots and those bearing corn, a feature which should be expected if an increase of vertical distance diminishes the rate at which water can be moved toward the surface.

The abrupt rise of the water in all of the wells shown on the left margin of Plate I was due to direct percolation of water following the rainfall of a little more than 1.1 inch shown at the foot of the plate. Examining these rises in detail, it will be seen that the two shallowest wells, Nos. 5 and 41 responded at once, while the others lagged behind, varying lengths of time, the highest point not being reached in the deepest wells, Nos. 46, 45, and 28, until after the lapse of 48 to 72 hours after the rain began. It will be noticed, also, that wells 46 and 45, which are in the more sandy soil, show only the general rise of the whole ground-water surface, while all the others show by the abrupt fall of the water that there has been a lateral percolation of water into them.

There are other long period and nearly synchronous rises shown by the curves which are common to all of the wells, but which do not appear to be so plainly the direct result of percolation, although all of them occur near or at the time of rainfalls of greater or less amounts. These are six in number, the last one being double; the first occurred after July 2, following a rainfall of about .5 inch, but is of small magnitude; the second is larger and follows a similar rain which fell on the 14th; the third, a very marked one, following the rains of the 26th to 29th, but the culminating point is not reached until August 2, where there is another rain of .05 inch, and six days later than the main fall of rain; following August 8, the fourth occurs after a rain of about .05 inch; the fifth is very slight except in well 27, and occurrs two days later than a rainfall of .12 inch; while the last and most pronounced rise of all except the one first referred to attains its summit five days after a rainfall of 1.3 inch.

The surface soil had become very dry just before all these rains, crops were suffering for water badly, and no one of the drains showed signs of discharging, whereas after the first period of rise they did. It does not appear to me, therefore, that these can be cases of rise in the ground-water due to percolation from the surface.

If these are in reality not cases of direct percolation, such

fluctuations might be accounted for in this particular locality by supposing that the higher ground, which the map shows to lie between the area under consideration and the lake, retards surface evaporation, as would be the case on other surrounding high lands, while the lower tract, where the wells are located, lying closer to standing water in the ground might permit more rapid lowering of the water surface by the greater effect of evaporation being added to that of drainage so that the level became here depressed below the level normal to the drainage resistance. If this had really occurred, any cause which would diminish the rate of upward movement of the water to the surface from the ground water surface would permit the level to rise toward the normal drainage level, and thus develop the fluctuations noted. A really serious objection to this view is found in the fact that wetting the surface of soil under certain conditions of dryness induces a more rapid movement of the water toward the surface from below, sometimes through depths as great as four feet, as direct observations have shown. There is, however, no evidence presented by the character of the curves under consideration that such an increased movement has developed a more rapid fall of the ground-water as should be true if the influence in question extended to that depth.

But the most remarkable peculiarity presented by these curves is the pronounced, and in some cases extremely large, diurnal fluctuations in the level of water in these wells. The curves show that there is a general tendency for the water either to rise during the night or else to fall less rapidly than during the day, and these will be referred to again.

RELATION OF THE RATE OF FALL IN THE GROUND-WATER SURFACE TO BAROMETRIC PRESSURE.

To ascertain whether there is a difference in the mean rate of fall of the ground-water surface, when judged by well measurements, the data obtained through the use of the micrometer have been tabulated in such a manner as to

show the amount of change in the water-level during the interval from the highest barometer to the following lowest pressure, which is not less than .1 inch lower, and this has been compared with the change which was found to occur during the following interval of barometric rise to the highest point, which was not less than .1 inch higher.

To render the amounts of change during the different periods comparable, the mean daily rate of change has been determined by dividing the total change observed in each period by the number of days in them. Since rainy periods are associated with times of low barometric pressure, whatever percolation may have occurred during periods of falling barometer would tend to diminish the normal fall of water for times of low pressure, and at the same time tend to increase the fall during periods of high pressure, except at times of large rainfall, which caused the period of percolation to extend into or across one or more periods of high pressure.

Table showing mean daily rate of change in the ground water-level associated with rising and falling barometer.

Period.	Date.	Rainfall	Changes.			
			Barometer rising.		Barometer falling.	
			Barometer.	Wells.	Wells.	Barometer.
	1883.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
1	September 18-23	.24	+.59	—.121	...	...
2	September 23-26	.01	...	...	+.116	—.73
3	September 26-29	...	.74	—.212	...	...
4	September 29-October 1	...	...	...	+.153	.85
5	October 1-2	...	.63	—.895	...	...
6	October 2-3	...	.61	—.141	...	...
7	October 3-4	...	...	...	+.096	.34
8	October 4-6	...	.33	—.192	...	...
9	October 9-13	...	...	...	—.015	.27
10	October 13-14	...	.19	—.233	...	...
11	October 14-16	.13	...	...	+.077	.22
12	October 16-18	.76	.35	—.103	...	...

Table showing mean daily rate of change in the ground water level.—Continued.

Period.	DATE.	Rainfall.	CHANGES.			
			Barometer rising.		Barometer falling.	
			Barometer.	Wells.	Wells.	Barometer.
	1888.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
13	October 18–19	....	....	....	+.640	.31
14	October 19–21	....	.52	—.184	....	....
15	October 21–27	.79	....	....	+.046	.60
16	October 27–30	....	.42	—.129	....	....
17	October 30–31	....	....	....	+.243	.34
18	October 31–November 1	....	.10	—.247	....	....
19	November 1–2	.05	....	....	+.307	.19
20	November 2–3	.41	.81	—.123	....	....
21	November 3–5	....	....	....	+.043	.22
22	November 5–7	.17	.31	—.130	....	....
23	November 7–10	.58	....	....	+.236	.50
24	November 16–20	....	.51	—.149	....	....
25	November 20–23	....	....	....	—.045	.28
26	December 3–5	....	....	....	—.078	.44
27	December 5–6	....	.53	—.240	....	....
28	December 6–7	....	....	....	+.180	.29
29	December 11–14	....	.35	—.130	....	....
	1889.					
30	May 3–7	....	....	....	—.103	.60
31	May 7–9	.30	.34	—.274	....	....
32	May 9–10	.15	....	....	+.045	.11
33	May 10–11	....	.12	—.233	....	....
34	May 11–16	.44	....	....	—.062	.23
35	May 16–22	1.01	.34	—.115	....	....
36	May 22–23	....	....	....	+.045	.23
37	May 23–25	.09	.22	—.210	....	....
38	May 25–27	1.02	....	....	+.398	.38
39	May 27–30	....	.39	—.245	....	....
40	May 30–June 3	.04	....	....	—.016	.33
41	June 3–6	....	.16	—.182	....	....
42	June 6–7	.07	....	....	+.001	.29
43	June 7–10	.58	.45	—.037	....	....

11—Ex.

Table showing mean daily rate of change in the ground water level.—Continued.

Period.	Date.	Rainfall.	Changes. Barometer rising. Barometer.	Barometer rising. Wells.	Barometer falling. Wells.	Barometer falling. Barometer.
	1899.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
44	June 10-15				— .153	.07
45	June 15-19	1.15			+ .211	.37
46	June 19-24	.10	.68	— .296		
47	June 24-26				— .149	.81
48	July 3-6	.23	.83	— .173		
49	July 6-9				— .305	.25
50	July 9-11		.16	— .233		
51	July 11-12				— .353	.24
52	July 12-16	.49	.28	— .072		
53	July 16-18				— .148	.43
54	July 18-24		.37	— .214		
55	July 24-28	.83			— .080	.38
56	July 28-31	.29	.48	— .036		
57	July 31-August 1				— .084	.22
58	August 1-6	.05	.30	— .165		
59	August 6-8				— .199	.28
60	August 8-11	.50	.20	— .017		
61	August 11-13				— .139	.30
62	August 13-17	.05	.24	— .129		
63	August 17-20				— .220	.28
64	August 20-26	.12	.34	— .197		
65	August 26-28				— .216	.12
66	August 28-31		.17	— .242		
67	August 31-September 4	.03			— .169	.47
68	September 4-11	1.44	.43	+ .204		
69	September 11-14				— .102	.31
70	September 14-16	.23	.25	— .114		
71	September 18-20				— .074	.48
72	September 20-22		.44	— .184		
73	September 22-23				— .060	.25
74	September 23-27	.09	.47	— .101		
75	September 27-30	.14			— .040	.53
76	September 30-October 2		.39	— .142		

Table showing mean daily rate of change in the ground water level—Continued.

Period.	Date.	Rainfall.	Changes. Barometer rising. Barometer.	Changes. Barometer rising. Wells.	Changes. Barometer falling. Wells.	Changes. Barometer falling. Barometer.
	1889.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
77	October 2-3				— .126	.18
78	October 3-4		.37	— .215		
79	October 4-5				— .099	.24
80	October 12-14		.56	— .104		
81	October 14-19				— .030	.60
82	October 19-23		.58	— .060		
83	October 23 25				+ .106	.80
84	October 25-29		.48	— .070		
85	October 29-November 2	.31			+ .097	.62
86	November 2-5	.03	.95	— .147		
87	November 5-13	.07			+ .110	.67
	1890.					
88	June 2-5	2.97			+7.162	.32
89	June 5-9	.22	51	—2.931		
90	June 14-16	1.76	.23	+6.840		
*96	June 19-21	.83			+2.105	.24
97	June 21-23	.38	.13	+ .138		
98	June 23-24				— .932	.10
99	June 24-26	.48	.12	— .302		
100	June 26-July 1	.025			— .724	.24
101	July 1-5	.11	.31	— .545		
102	July 5-7	.11			— .289	.24
103	July 7-10		.36	— .549		
104	July 10-14				— .196	.39
105	July 14-16	.10	.41	— .354		
106	July 16-17				— .216	.26
107	July 17-19	.09	.24	— .407		
108	July 21-24	.475			— .201	.45
109	August 1-3				— .284	.14
110	August 3-6	1.105	.21	— .106		
111	August 6-8				— .122	.39

* Some periods in the original tables are omitted here.

Table showing mean daily rate of change in the ground-water level— Continued.

Period.	DATE.	Rainfall.	CHANGES.			
			Barometer rising.		Barometer falling.	
			Barometer.	Wells.	Wells.	Barometer.
	1890.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inch.*
112	August 8-11	.....	.46	— .332	.....	.....
113	August 11-13	.....	.....	.....	— .046	.21
114	August 13-15	.....	.17	— .361	.....	.....
115	August 15-16	.15	.....	.....	+ .004	.15
116	August 16-18	.96	.19	— .065	.....	.....
117	August 18-19	.10	.....	.....	+ .055	.23
118	August 19-20	.....	.15	— .207	.....	.....
119	August 20-21	.05	.....	.....	— .001	.23
120	August 21-23	.06	.40	— .338	.....	.....
121	August 23-26	1.35	.....	.....	+ .218	.52
122	August 26-30	.06	.32	— .235	.....	.....
	1891.					
123	April 8-10	.....	.....	.....	+2.456	.54
124	April 10-12	.....	.41	+1.270	.....	.....
125	April 12-14	.18	.....	.....	— .127	.31
126	April 14-16	.30	.42	+ .593	.....	.....
127	April 16-18	.....	.....	.....	+ .328	.32
128	April 18-20	.....	.24	— .505	.....	.....
129	April 20-23	.52	.....	.....	+1.013	.30
130	April 23-24	.....	.17	— .681	.....	.....
131	April 27-28	.23	.30	— .990	.....	.....

If we compare the changes in water-level which occurred during the two long intervals in 1888, when there was no rain, and the long one in 1889 at times of rising and falling barometer we shall have, for the mean daily change, the following results:

	Rising barometer.	Falling barometer.
	Inch.	*Inch.*
Periods 3 to 10	—.395	+.068
Periods 21 to 29	—.173	+.019
Periods 76 to 84	—.118	—.037
General mean	—.229	+.017

For these intervals of time, therefore, there was a mean daily fall of water surface during the days of rising barometer amounting to .229 inch, while during the periods of falling barometer there was a mean daily rise of .017 inch.

If we determine the mean daily change during all the periods of rising barometer in 1888 and 1889, and in those of 1890, after the heavy rains preceding July 5, and compare these with that which occurred during periods of falling barometer for the same interval of time, we shall have the results given below:

Mean daily change for—	Rising barometer.	Falling barometer.
	Inch.	*Inch.*
1888	—.235	+.141
1889	—.143	—.046
1890	—.295	—.098
General mean	—.221	—.001

These observations show that a generalized curve representing the fall of water in a well would have a form such that the steeper slopes span intervals of rising barometer and the less steep ones periods of falling barometer.

RATE OF CHANGE IN THE GROUND-WATER LEVEL FROM MORNING TO EVENING AND FROM EVENING TO MORNING.

As has already been pointed out, there is a general tendency for the water-level of the wells under consideration to fall more rapidly during the day than during the night, and it is proposed, in the following tables, to give some of the data upon which the above statement is founded. The observations for the several wells have been grouped into periods and the total change which occurred from morning to evening and again from evening to morning for each of these periods determined. To reduce these all to a common unit, the observed total change for each well during a given period has been treated as follows:

Let a = total observed change in well during a given period;

b=length of time, in hours, between the a. m. and p. m., or p. m. and a. m. observation.

n=number of observations in the period.

Then, $\frac{a}{bn} \cdot 1{,}000$=change for 1,000 hours.

This is supposing the observed mean rate to have continued during 1,000 hours. The following table contains the result of this treatment for the wells there specified by Arabic numerals at the left during the periods numbered in Roman at the top:

Table showing changes in the level of ground-water from morning to evening and from evening to morning, computed for 1,000 hours.

No. of well.	Period I.		Period II.		Period III.		Period IV.		Period V.	
	A. M. to P. M.	P. M. to A. M.	A. M. to P. M	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.
26.......	—12.632	— 1.128	— 8.259	— 5.266	+3.158	— 2.228	+ 1.749	+ 2.517	— 6.551	+2.586
27.... ..	—14.211	+ 1.505	+ .486	—11.285	+2.915	— 5.517	— .486	+ 1.379	— 2.936	—2.351
28... ...	— 2.297	— 8.276	+ 1.493	—13.166	+7.288	—10.000	+ 3.887	— 1.379	— 2.232	— 2.351
5.......	....	......	—12.105	+ 4.966	— 4.060	+2.228	+ .194	+ .552	— 8.808	+ 5.408
13.......	— 9 473	+ 3.009	— 6.078	+ 1.316	— .486	— 1.379	— 1.263	— 1.931	... .	....
14.......	—12.634	+ .460	....	....	....	... .	....	....	....	....
15.......	— 9.478	+ .753	— 5.830	.000	— .541	+ .700	+ 1.069	— 1.103	....	....
16.......	—10.526	+ 3.762	— 3.887	— 1.505	— 2.707	+2.228	— .094	+ .759	....	....
17.......	—15.789	+ 5.642	. ...	....	.... ..	....	....	....	....	... .
6.......	—25.263	+ 8.276	—15.304	+ .564	— 4.060	+1 910	— 3.401	+ 3.793	....	....
7.......	—28.431	+11.285	.. ..	....	.. ....	....	....	....	. .....	....
39... ...	—41.474	+12.260	— 5.831	—28.585	+8.745	+ 6.207	+ 2.818	+12.483	....	....
Average	—16.655	+ 3.390	— 6.093	— 5.885	+ 1.594	— .750	+ .519	+ 1.897	— 5.18[illegible]	+8.23

Number of well.	Period VI.		Period VII.		Period VIII.		Period IX.	
	A. M. to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A M.	A. M to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.
26	—11.539	+ 9.962	—15.351	— 1.069	—11 348	— 9.665	— 8.862	— .271
27...	— .976	— 1.097	—10.526	— 4.774	— 3.691	—13 163	— 5.215	— 4.655
28	— 1.144	— 1.628	— 5.012	—10.688	— 3.445	—10.757	— 4.373	— 7.857
5........	—10.086	+10.934	—15.915	+ 3 527	—21.821	— 4.634	—91.452	+86.593
40..... ..	— 4.541	— 1.593	— 7.205	— 8.194	— 2.969	—10.834	— 5.028	— 7.390
41........	— 2.725	— 2.442	— 8.145	— 6.769	— 6.582	— 7.278	— 5.879	— 5.459
42........	— 2.859	— .177	—11.812	— 7.909	— 7.737	— 8.047	— 6.966	— 4.660
43........	— 6.123	+ 4.317	—10.714	— 4.916	— 7.605	— 7.035	— 6 203	— 5.714
44..... ..	— 5.753	+ 5.698	—10.464	— 8.967	— 5.777	—10.951	— 9.719	— 2.179
45........	+ .437	+ 1.840	—11.779	—10.118	— 7.574	—10.015	— 7.192	— 4 877
46........	—20.600	+24.738	—12.218	—11.044	—12.955	— 5.166	— 9.491	— 1.656
Average.	— 5.992	+ 4.596	—10.834	— 6.429	— 8.319	— 8.872	—14.580	+ 3.834

Number of well.	Period X.		Period XI.		Period XII.		Period XIII.	
	A. M. to P. M.	P. M to A. M.	A. M. to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.	A. M to P. M.	P. M. to A. M.
26	— 8.847	— 1.985	—11 544	— 8.371	+ .027	— 2.643	— 7 042	—11.893
27	— 6.254	— 4.300	— 5.666	— 1.326	— 1 327	— .078	— 8.622	—10.402
28	— 5.967	— 3.026	— 9.403	— 7.791	+ .073	— 2.771	— 12.422	— 8.161
5	—11.492	— .936	—13.676	— 6.121	....	....	....	....
40	— 4.385	— 6.769	— 5.206	— 9.709	— 3.273	— 1 964	— 5.867	— 9.357
41	— 6.748	— 5.278	— 8.763	— 7.918	— 1.427	— 2.805	—10.133	— 7.866
42	—12.575	+ .088	—28.963	+12.212	— .864	— 1.800	—10.655	— 7.286
43	— 6.422	— 4.954	—24.451	+10.271	— 3.527	— .550	....	....
44	—11 071	— .495	—16.768	— 1.406	— 3 318	— 2.393	—11.600	— 8.203
45	—35.485	+23.615	—50 897	+29.202	— 1.036	— 8.790	—10.167	— 3.509
46	—11.087	— 3.128	—31.844	+ 9.795	+ 1.336	— .571	—13.222	— 6.661
47	....	....	....	....	+ 1.973	— 1.628	—11.244	—11.232
Average.	—10.939	— .652	—18.831	+ 1.704	— 1.033	— 1.644	— 9.179	— 8.467

This table shows that in the majority of cases the rate of fall in the ground-water level is more rapid during the hours from 6 a. m. to 6 p. m., than it is from 6 p. m. to 6 a. m. Now, while there are numerous exceptions to this statement, yet the exceptions are largely confined either to certain wells or else to particular periods, as the following condensed tabulation will show:

		Agreements.	Exceptions.
In well 26 during	13 periods there were	10	3
In well 27 during	13 periods there were	8	5
In well 28 during	13 periods there were	3	10
In well 5 during	10 periods there were	10	0
In well 13 during	4 periods there were	2	2
In well 14 during	1 period there was	1	0
In well 15 during	4 periods there were	3	1
In well 16 during	4 periods there were	4	0
In well 17 during	1 period there was	1	0
In well 6 during	4 periods there were	4	0
In well 7 during	1 period there was	1	0
In well 39 during	4 periods there were	2	2
In well 40 during	8 periods there were	2	6
In well 41 during	8 periods there were	6	2
In well 42 during	8 periods there were	6	
In well 43 during	7 periods there were	7	

	Agreements.	Exceptions.
In well 41 during 8 periods there were	7	1
In well 45 during 8 periods there were	7	1
In well 46 during 8 periods there were	7	1
In well 47 during 2 periods there were	1	1
Making in 129	92	37

There are thus shown to be 71 per cent. of the cases where the mean fall during the daytime is greater than it is during the night. Then, again, of the 37 exceptions, 21 are found in 3 wells and 10 are found in one. If we make the tabulation by periods the case will stand as below:

1888.	Agreements.	Exceptions.
September 18 to 29, Period I, of 11 wells there were	10	1
October 1 to 14, Period II, of 9 wells there were	6	3
October 15 to 28, Period III, of 9 wells there were	4	5
October 29 to November 10, Period IV, of 9 wells there were	6	3
1889.		
May 19 to June 1, Period V, of 4 wells there were	3	1
June 4 to 18, Period VI, of 11 wells there were	9	2
June 20 to 27, Period VII, of 11 wells there were	9	2
July 3 to 17, Period VIII, of 11 wells there were	4	7
July 18 to August 1, Period IX, of 11 wells there were	9	2
August 2 to 16, Period X, of 11 wells there were	10	1
August 17 to 31, Period XI, of 11 wells there were	10	1
1891.		
January 19 to 31, Period XII, of 11 wells there were	5	6
February 14 to 22, Period XIII, of 10 wells there were	7	3

Making in all 129 cases, with 92 agreements and 37 exceptions.

Here, again, 18 of the exceptions occur in periods III, VIII, and XII.

Determining the average change of all of the wells during all of the periods, it is found to be—8.583 inches in 1,000 day hours, and—1.309 per 1,000 night hours. Making a similar determination for periods VI to XIII, inclusive, when the largest number of wells were being measured at the same time, we get—9.972 inches as the change during the day, and—1.917 as the change during the night for each 1,000 hours.

AUTOMATIC RECORDS OF THE FLUCTUATIONS IN THE LEVEL OF GROUND-WATER.

It became evident very soon, in the study of the changes which take place in the level of ground-water, that not only continuous but synchonous records would be required before the real character and extent of these movements could be made known, and early in the summer of 1891 the practicability of obtaining continuous records was established by mounting a pen upon an axis so that a float, resting upon the surface of the water in a well would cause

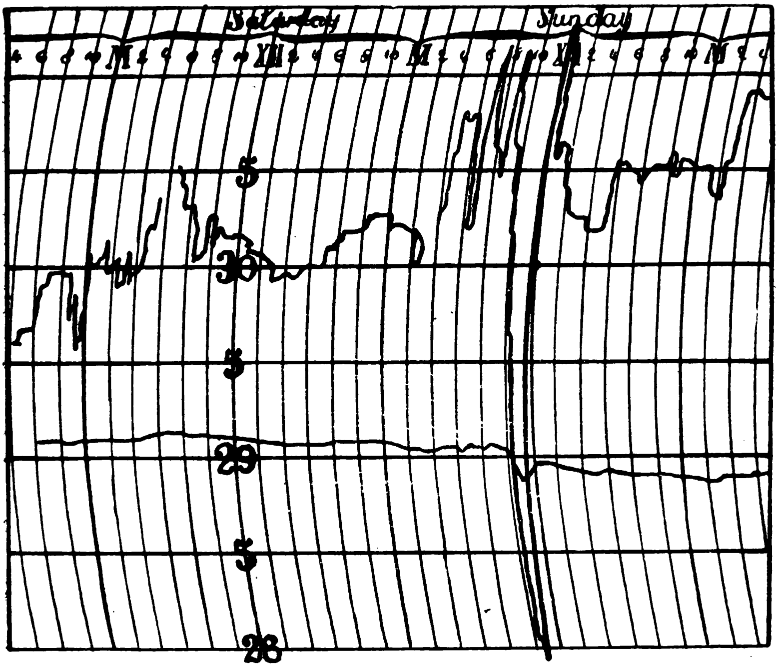


FIG. 34.—Automatic record of fluctuations of water in well 48, from 6 p. m., May 30, to 6 a. m., June 1, 1891, with the synchronous barograph record below.

the pen to record the movement of the water upon a sheet carried by the drum of a thermograph, and Fig. 34 is a reproduction of one of the earliest records thus obtained, the instrument being placed in well 48, which has a depth of 40 feet and is tubed with 6 inch iron pipe down to rock, 37 feet below the surface. There was in this well at the time

the first records were obtained 20 feet of water, and it had just been sunk. Water was first reached at a depth of 25 feet, but after the drill entered the sandstone 2.5 feet the supply of water to the well considerably increased and the head raised 5 feet.

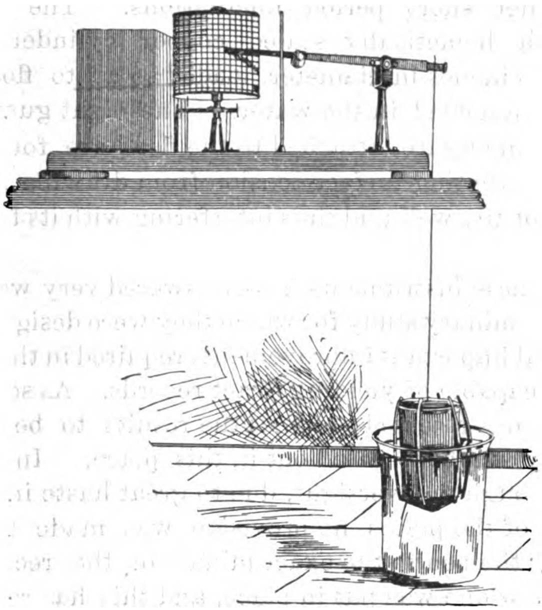


FIG. 35.—Self-recording apparatus for registering fluctuations of water-level in wells.

The financial assistance rendered in this investigation by the Weather Bureau, through the U. S. Department of Agriculture, made it possible to have twelve special recording instruments constructed for the purpose of this study, one of which is shown in Fig. 35. The instrument consists of a drum, carrying a record sheet, which is driven by a double marine eight day clock movement in ten of the instruments, and a one-day movement in the other two. A copper float connected with a lever working upon cornical bearings

NOTE.—It is due to the manufacturer of these instruments, Mr. Henry J. Green, to say here that, considering the few weeks he had at his disposal for the construction of them, and the lack of specific details to guide him, the order was exceptionally well filled.

transmits the movements of the water surface to the pen. The arm of the lever to which the float is attached is one-third the length of that carrying the pen, thus producing a curve having an amplitude three times the normal. The fluctuations in most wells, however, have been found so large as not really to require this amplification for any but the smaller short period fluctuations. The float consists of a hemetically sealed copper cylinder 6 inches long and 3 inches in diameter, loaded so as to float about one-half immersed in the water. The eight guard wires, shown in the figure, attached to the fl at are for the purpose of preventing surface tension from drawing it against the wall of the well and thus interfering with its free movement.

While these instruments have answered very well for the hasty preliminary study for which they were designed, there are several important improvements required in them before they are capable of yielding exact records. As some of the imperfections referred to affect the results to be reported here, they will be pointed out in this place. In the first place, through an oversight, due to great haste in the construction of the pieces, no provision was made for easily adjusting the pen to the exact minute on the record sheet when a new one was put in place, and this has rendered it difficult to exactly combine the records so as to show the true time relations existing between the flucuations of the different wells. In the second place, the screw movement by which the clock is coupled with the drum introduces a perodic error which throws the recorded events slightly out of their true time, but is so small as to seriously affect only the short period fluctuations, and time has not permitted the application of any correction for it. This method of connection also introduces a third source of error by the considerable slack movement which it necessitates, and to overcome which no provision was made. In setting the clock the drum could be placed, of course, so as to take up all slack, but the errors introduced from this source come through any jar which the instrument might sustain, and in some cases might exceed one hour in time. These facts

should be constantly borne in mind when considering the continuous records presented in this report.

THE COMPLEX CHARACTER OF FLUCTUATIONS TO WHICH THE SURFACE OF GROUND-WATER IS SUBJECT.

It is proposed to enumerate here, as preliminary to the presentation of the results which have been secured through the self-recording instrument and associated studies, some of the conditions which affect the level of ground-water, or may be expected to do so.

Possible secular changes in the level of ground-water.

It is a common remark made by many of the older settlers of this state and of Illinois, that the water stands permanently lower in the wells than it did in earlier times, and that many tracts of land which it was than impossible to get upon with a team are now hard enough to do so without difficulty. Without attempting to assign a cause for these supposed or real changes in the level of the ground-water, attention may be called to some changes now in progress tending to produce such alterations as that referred to.

In those sections of country undergoing secular changes of level due to movements of the earth's superficial strata, it is evident that all artesian basins experiencing any differential movement that would alter the relative height of the supply and drainage portions must tend to have established new drainage rates for them, and if the drainage portion of such a basin is being progressively lowered, relatively, by any cause, while the mean percolation of rain into it remains the same, the level of the ground-water would tend to progressively decline.

Then again the depression, by surface erosion, of river beds or the outlet of lakes into which the ground-water of the surrounding highlands drains, must have a tendency to increase the drainage gradient and hence to lower the level of ground-water until equilibrium is established between the drainage and the mean annual percolation.

The water which percolates into the ground and again emerges from it carries away, both in solution and in mechanical suspension, large quantities of the rock constituents with which it has come in contact; and this, unless counteracted by other changes, must tend to develop an increasing porosity or widening of the passageways through which the water moves and so to decrease the resistance to drainage and hence to lower the general level of ground-water in the region so affected.

If in any considerable tract of country the mean surface consumption of water is increased by a material increase in the annual production of dry matter per acre in the form of vegetation, there must necessarily be a decrease in the total drainage from that section, and for this reason a tendency to develop a lower stage of water in the ground, and through this a drying and hardening of marsh lands such as has been referred to. When it is stated that experiments conducted in England and Germany, and also at this station, all agree in showing that as much as 325 pounds of water are required to be withdrawn from the soil by the roots of plants in the production of each pound of dry matter, it is evident that to double the mean annual production of dry matter in a country must have an appreciable effect upon either the superficial or underground drainage from that region, and if upon the underground drainage to lower the height of ground-water there and through this to lower the level of lakes, and to harden the marshy lands.

Short-period changes in the level of ground-water.

As has already been pointed out, seasonal and annual changes in the amount of water which falls upon the surface of the ground and percolates into it, have a tendency to develop stages of high and low ground-water in regions so affected.

Since changes in temperature very materially influence the viscosity of liquids, and since variations in the viscosity affect the flow of water through narrow passages like

capillary tubes, it may be expected, as will be shown in another place, that both seasonal changes in soil temperature and mean annual ones also exert an influnnce in developing fluctuations in the level of ground-water through a modification of the rate of percolation and the rate of underground drainage.

Oscillations in the level of ground-water.

Besides the changes in the level of ground-water already pointed out, its general surface is further subject to extremely numerous oscillations of small extent, some of which are almost microscopic in amplitude; indeed, the times of even approximate quiet appear to be extremely rare. The equilibrium of the water in the capillary soil spaces above the surface of the ground-water is so unstable that apparently the slightest cause is sufficient to upset it, causing the water to flow out into the non-capillary spaces, but only to be returned again, often on a moment's notice. There appears to be a zone of soil particles of undetermined depth into and out of which there is a constant ebb and flow of water. The observations to be presented show that oscillations of atmospheric pressure of almost every character affect this underground water surface. The longer period barometric changes associated with cyclones depress or raise the water surface, as the case may be; the shorter period changes, which accompany thunderstorms, are registered there, and there are movements which are coincident in time with the semi-diurnal barometric changes. The diurnal changes in soil temperature, under favorable conditions, produce corresponding rises and falls of the water-surface; and the passage of a train, even where the water is 20 feet below the surface, causes the non-capillary spaces to fill up and empty themselves again as the moving weight approaches and recedes. This ground-water ocean surface, therefore, like that of the open sea, knows never one moment of rest. The geologic and agricultural significance of these movements must be very great, for here is a water washed zone of rock and soil, having the combined area of all land above ocean level, unless we must except those of

the polar zones, which is alternately flooded with water and then exposed to air; and this zone rising and falling through greater and lesser distances, according to the secular and short period changes in the level of the ground-water, must greatly exaggerate the solvent power of soil water over what it would be did these oscillations not exist.

INFLUENCE OF BAROMETRIC CHANGES ON THE RATE OF FLOW FROM SPRINGS, ARTESIAN WELLS AND TILE DRAINS.

Three of the self-recording instruments referred to were placed, one upon a spring at Whitewater, Wis., one upon an artesian well 300 feet deep situated one-half a mile distant from the spring, and the third so as to register any change which might occur in the rate of flow of water from a tile drain on the Experiment Station Farm.

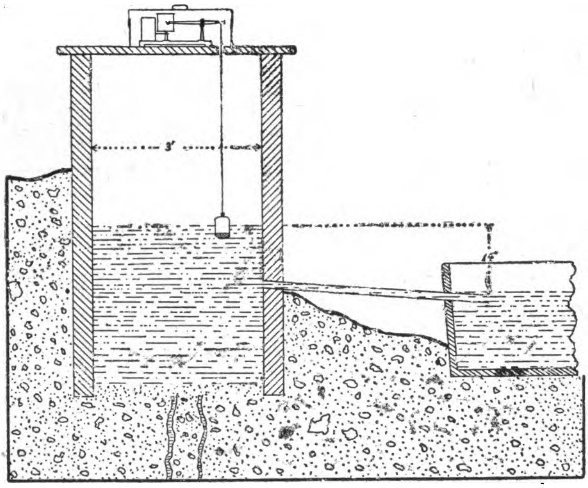


FIG. 36—Method of recording changes in the rate of flow of water from drains and springs.

The method of enabling the instrument to record changes in the rate of flow of water is illustrated in Fig. 36, which shows how it was placed in the spring at Whitewater. The spring in question was encased in a wooden cylinder 3 feet in diameter and the water brought by it discharged through a 1¼ inch gas pipe, 4 feet long, into a vat used for setting

milk cans in. The top of the spring curb was covered and the instrument placed as represented in the figure. In the case of the artesian well the principle was the same, for the well discharged from the side of the 6-inch tube through a ¾-inch gas pipe a few inches long, and the float rested directly upon the surface of the water, which stood at all

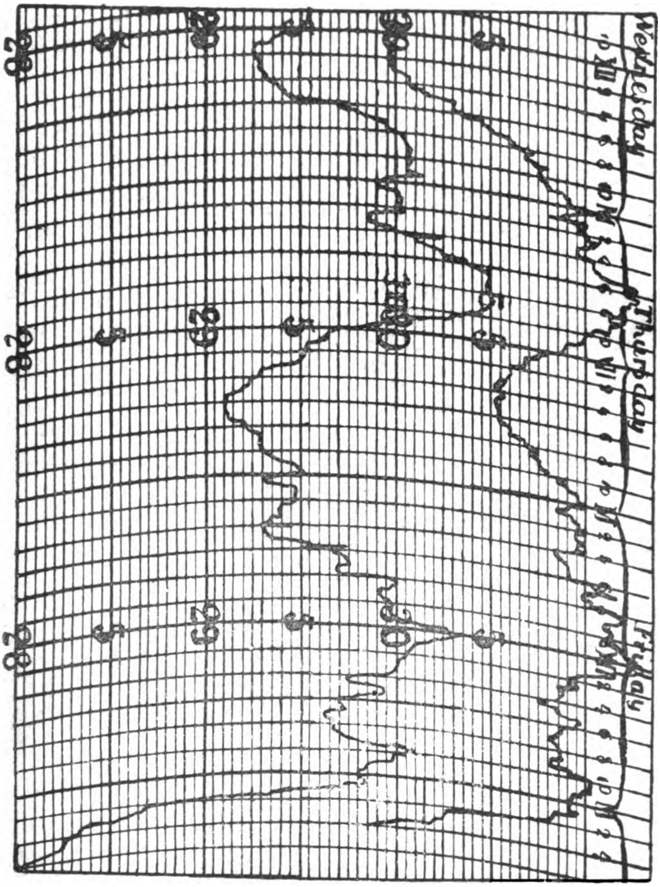


FIG. 37.—Synchronous records, showing variations in the rate of flow of water from a spring and from an artesian well at Whitewater, Wis.

times above the level of the discharge. In the case of the tile drain, the water flowed into a receptacle which had an orifice near the bottom, whose capacity could be altered so as not to allow the receptacle to become full and overflow

the top. In all of these cases any change in the rate of flow of water from the ground would produce a change in the head of water discharging through the respective pipes, thus causing the float to rise or fall as the rate of flow increased or decreased.

A facsimile of the synchronous curves obtained from the spring and from the well during two and one-half days is shown in Fig. 37, from which it will be seen that while they are not alike in the minuter oscillations, there is yet a remarkable agreement between them.

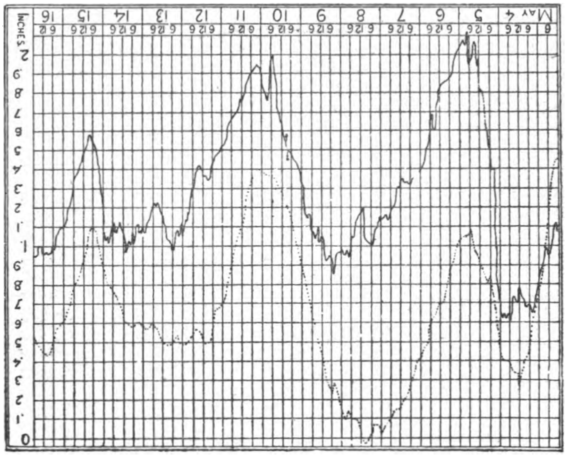


FIG. 38.—Fluctuations in the head of a spring at Whitewater, Wis., from May 4 to May 16, and the barograph record at Madison for the same period. Both reduced to natural scale.

There was no barometer record kept at the place where the well and spring are, but the barograph records at the Experiment Station are available for comparison with these curves, but it must be borne in mind that the barograph is situated 45 miles to the westward of the locality under consideration. In Fig. 38 the records of the barograph and that of the spring for May 4 to 16 are placed in juxtaposition, the minor oscillations of the spring being omitted. It requires only a glance at these two curves to see that they are remarkably concordant, considering that they are separated by an interval of 45 miles and that the curves are in themselves so complex. It is true that the changes recorded

by the barograph fall a little earlier than the corresponding ones produced by the spring, but as the barometric changes are progressive from west to east a certain interval should be anticipated, even were there no lagging due to other causes.

So, too, when we compare the barometric curve with that obtained from the tile drain referred to, as shown in Fig. 39, it will be seen that there is here also a close agreement between most of the marked curves which the barograph shows and those produced from the fluctuations in the rate of discharge from the tile drain. The rapid increase in the rate of discharge on Sunday is due to percolation resulting from the rain of 1.10 inch falling during Saturday night and Sunday.

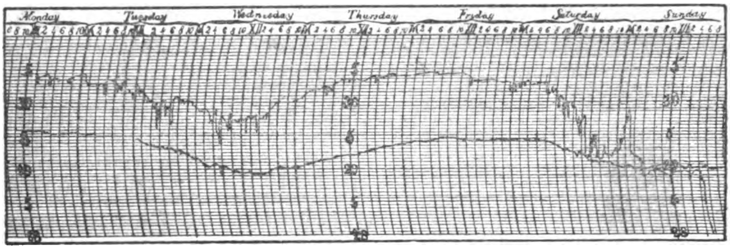


FIG. 39.—Synchronous changes in the rate of discharge of water from a drain, and the baromatic changes during one week.

The smaller short period fluctuations shown on the drain curve are a portion of them barometric, but not seen to be so because the amplitude of the barometer curve is too small to show their equivalents upon it; the very sharp shortest period curves are many of them due to the pumping action of the wind, which tends to suck air either out of or into the drain and thus modify the rate of discharge.

In the case of the spring under consideration, the barometric changes which occurred during the intervals when the records were kept caused the head to range from less than 12 inches to more than 14 inches, and this would give a theoretical variation in the rate of discharge amounting to 8 per cent., the water flowing this much faster during one interval of low barometer when compared with that taking

place during and immediately preceding high barometer. In the case of the tile drain, with the water discharging from the gauge under a head of .585 inch, a sudden rise in the barometer amounting to .1 inch decreased the head in the gauge almost as suddenly .15 inch, and considering the velocity of discharge to vary as the square root of the head, the water was discharging under the high pressure 15 per cent. less rapidly than previous to the change of atmospheric pressure.

The water supply at the waterworks for the city of Whitewater is derived from an artesian well 979 feet deep, the water flowing into a reservoir 106 feet in diameter in which there is an overflow pipe having an inside diameter at the top of 9.75 inches. The pumps are coupled directly to the well in such a manner as to draw upon the reservoir when the rate of flow from the wells does not equal that of pumping. Through the kindness of the proprietors, Messrs. C. G. Gray & Co., I was permitted to place one of my instruments in the reservoir so as to determine whether or not this well was subject to variations in the rate of flow analogous to those observed in the spring and shallower well near by already referred to. To obtain the rate of flow of water from the well the float of the recording instrument was placed upon the water in a cylinder which was partly submerged in the reservoir, the bottom of the cylinder being perforated with several small holes so as to establish communication with the water in the reservoir without allowing the float to be disturbed by wave action.

During the pumping, which occurred once daily, the water was lowered in the reservoir from 2 to 4 inches, and the instrument was so adjusted as to record the length of time required for the reservoir to regain its original level after pumping, and to show any change of head which might occur while the reservoir was overflowing.

One of the eight day instruments was first placed in the reservoir, and Fig. 40 shows a portion of the record obtained with it, where it will be seen that not only did the time required for the reservoir to regain its original level vary but

also that this level did not remain constant when once attained. It should be observed that the curve showing the rate of filling covers only the last portion of each day.

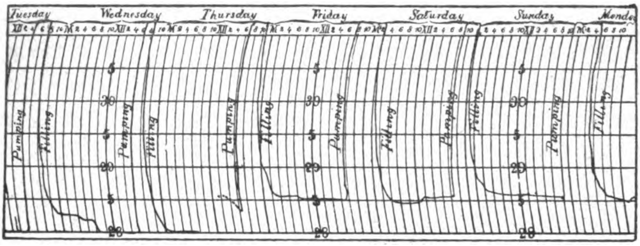


FIG. 40.—Changes in the rate of flow from the artesian well at the city water works, Whitewater, Wis.

In order to be able to measure the time of filling more exactly one of the one-day instruments was substituted for the one first used, and a record obtained during 10 consecutive days with results as given below:

Table showing variations in the rate of flow of water from the artesian well at the city waterworks, Whitewater, Wis., from May 31 *to June* 9, 1892.

	Cu. ft. per min.
May 31, well discharged 1103.09 cubic feet in 77.82 minutes,	= 14.175
June 1, well discharged 1103.09 cubic feet in 71.44 minutes,	= 15.441
June 2, well discharged 1103.09 cubic feet in 75.27 minutes,	= 14.655
June 3, well discharged 1103.09 cubic feet in 72.71 minutes,	= 15.171
June 4, well discharged 1103 09 cubic feet in 76.54 minutes,	= 14.412
June 5, well discharged 1103.09 cubic feet in 79.09 minutes,	= 13.947
June 6, well discharged 1103 09 cubic feet in 72.71 minutes,	= 15.171
June 7, well discharged 1103.09 cubic feet in 76.54 minutes,	= 14.412
June 8, well discharged 1103.09 cubic feet in 73 99 minutes,	= 14.909
June 9, well discharged 1103.09 cubic feet in 72.71 minutes,	= 15.171

On June 1, 7, and 8, at the time of sudden showers, the water-level in the reservoir changed so as to carry the float up through .1, .5, and .4 inch respectively, and this when the water had been overflowing at its normal height during several hours. The shower when the water rose more than .5 inch was a very heavy one, but all of them were of short duration. As the overflow was within three feet of the place occupied by the instrument it does not appear probable that any wind action, by forcing the water to that side could have produced the change

of level observed, and that this could have been the cause is rendered still more improbable by the fact that the water rose and fell so as to give a steady curve, as shown in Fig. 41. Neither does it appear possible that any shower could have increased the head to the extent observed, by direct precipitation into the reservoir, for the overflow pipe was never carrying water at near one-half of its full capacity. If no such explanation as has been suggested is admissible, the conclusion must be that these deep wells are subject to sudden increases in flow such as have been shown to be true of the spring, the drain, and the shallow artesian well referred to.

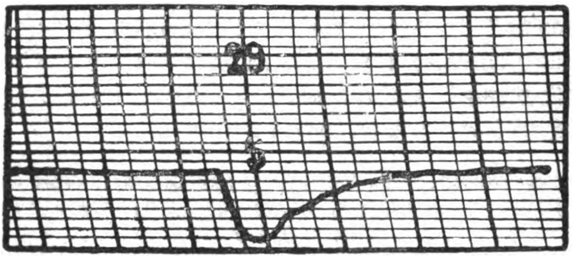


FIG. 41.—Sudden changes in the flow of water from the artesian well at the city water works, Whitewater, Wis. Natural scale.

It should be observed here also that the changes in the rate of flow recorded by the eight-day instrument are coincident in time, and also in character, with the changes which took place in the spring and other well in the same vicinity, and it would appear, therefore, that barometric changes exert a far reaching influence upon the underground drainage coming from any and all depths below the surface. The magnitude of this influence is so great also that the aggregate increase or decrease in the flow of water from large subterranean drainage areas, as low and high waves travel over them, must be absolutely very great and it would seem, capable of registration by suitable instruments on very many, if not upon all, rivers, and possibly all lakes as well.

BAROMETRIC OSCILLATIONS IN THE LEVEL OF WATER IN WELLS.

The evidence is overwhelming that barometric changes exert a very marked and nearly if not quite immediate influence upon the level of water in a well. That sudden and large changes in the barometer are closely associated with marked changes in the level of water in wells is strongly suggested by the fac simile curves shown in Fig. 33, already referred to on page 170, but here the amplitude of the barometer is too small to make a satisfactory comparison between them in any except the general features.

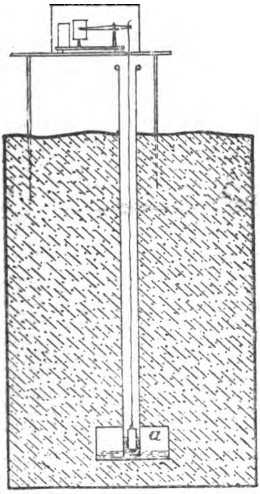


FIG. 42.—Construction of air barometer.

In order that a closer comparison might be made in this particular, the two one-day instruments were placed one upon well 48 and the other upon the air barometer represented in Fig. 42, which was constructed for this purpose and to ascertain whether or not some of the short period fluctuations shown both by the wells and by the spring and drain might not be due to a pumping action of the wind. This instrument, apart from the recording portion which has been described, consists of a galvanized iron cylinder, 4 inches in diameter and eight feet long, to the lower end of which is attached a cylinder of the same material 18 inches in diameter and 8 inches deep; this larger cylinder confines a quantity of air which, by its changes in volume alters the level of the water shown and thus causes the float to rise and fall with each change of atmospheric pressure. The air receptacle is placed six feet below the surface of the ground and the earth filled in over it so as to avoid marked temperature fluctuations. The instrument thus constructed proved to be quite satisfactory for the purpose designed, and has an amplitude five to six times that of the mercurial barometer.

How closely in accord the fluctuations recorded by this instrument and by the one placed upon the well are will be seen from Fig. 43, which shows the curves produced dur- the 10 hours closing 7:50 a. m. May 30, 1892. It will be seen that there are on the well curve two short interval changes, one upward near the left end and the other downward to the right of the center, which have no analogous ones in that of the air-barometer, otherwise there is an extraordinary agreement in all features except amplitude.

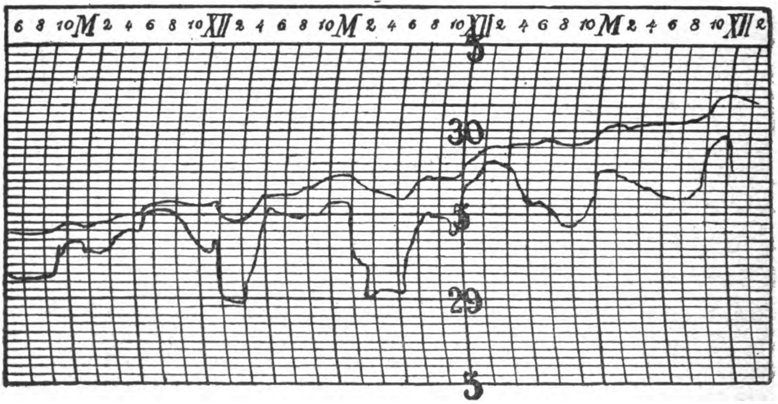


FIG. 43.—Sycchronism of barometer and well changes as recorded by one day instruments.

At times these barometric fluctuations are both of extreme amplitude and of great frequency also; this is clearly shown in Fig. 44, where the amplitude was so large as to require the pen to be set over four times between 2 p m. Monday and 6 a. m. Thursday, and at intervals during this period the changes were so rapid as to force the lines close together. The general frequency of these changes are better shown in Fig. 45, which is a tracing of the curve produced during 24 hours ending April 30. 1892, by well 48.

The synchronism of movement which the ground-water in different wells in the same locality exhibits is shown in Plates II to V, where the curves are reproduced so as to show the changes of level as they occurred from day to day.

It should be borne in mind in studying these plates that the direction of the movement of the water surface in the

well was opposite to that shown by the curve, a descent of the curve across the page meaning a rise of water in the well and *vice versa*, and this is true for all of the curves

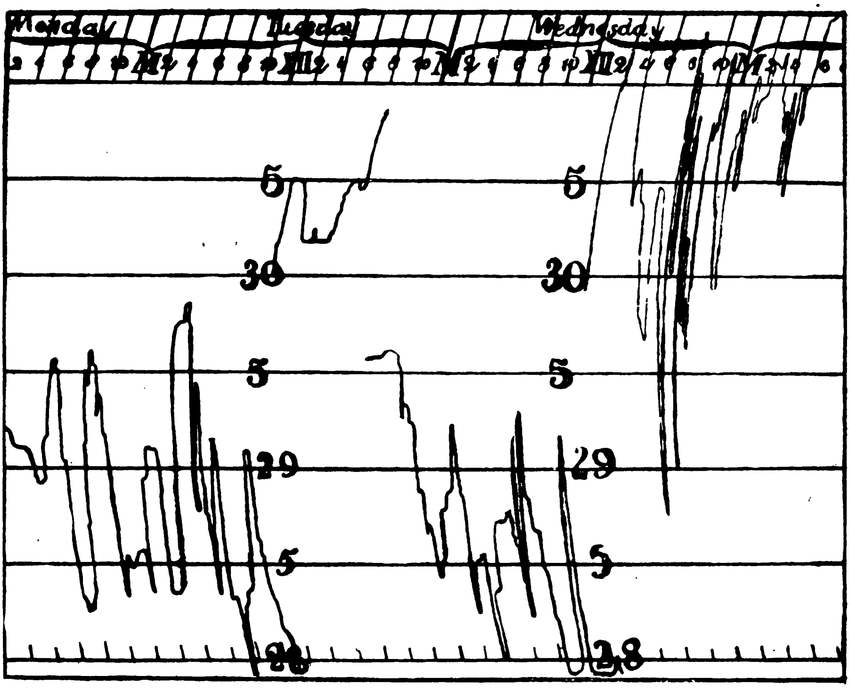


FIG. 44.—Complex character and wide amplitude sometimes occurring in the oscillations of water in wells.

obtained with the instruments used. Since a rise of the barometer is associated with a tendency of the water to fall in the well and a fall of the barometer with a tendency

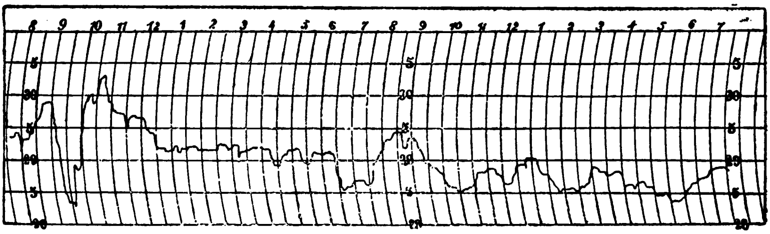


FIG. 45.—General character of fluctuations of water in well 48 during 24 hours.

to rise, the method of mounting the pen causes that of the barograph and that of these recording instruments to move in the same direction at the same time.

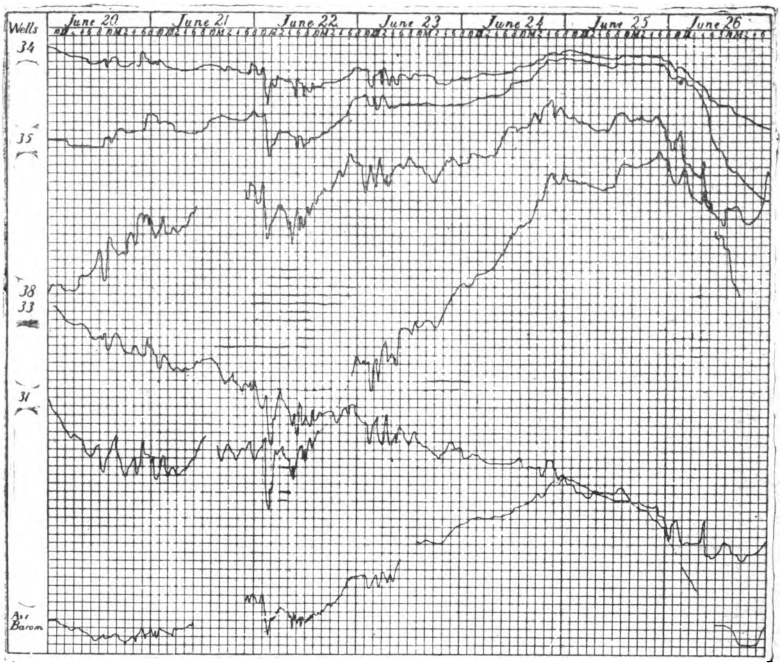


PLATE II.—Synchronous fluctuations in wells and air barometer from June 20 to 26, 1890.
Small squares represent one-tenth of an inch.

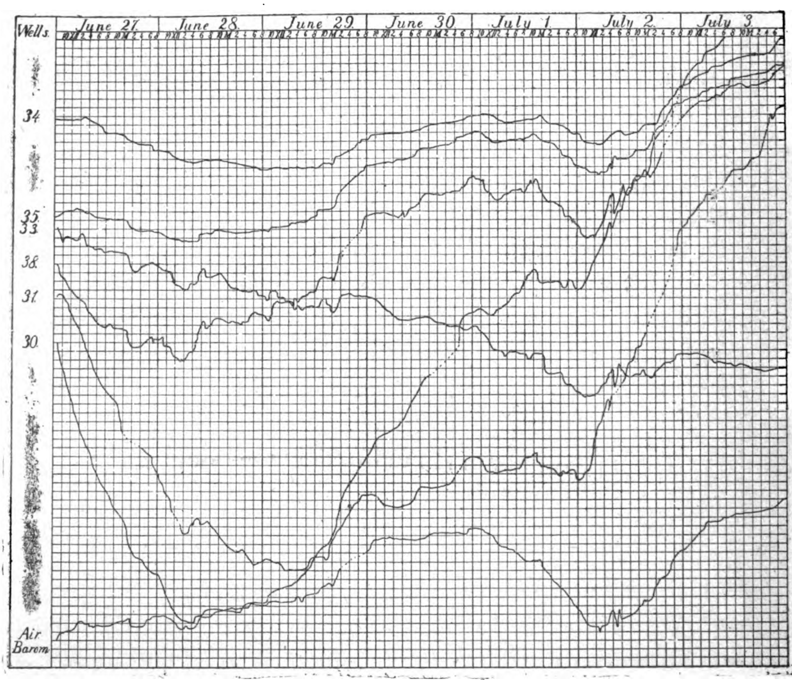


PLATE III.—Synchronous fluctuations in wells and air barometer from June 27 to July 3, 1892.
Small squares represent one-tenth of an inch.

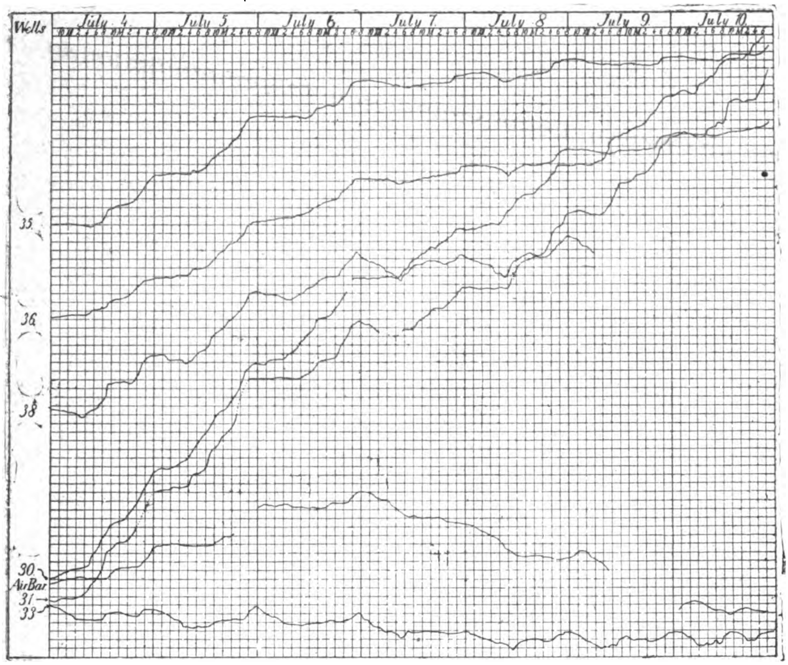


PLATE IV.—Synchronous fluctuations in wells and air barometer from July 4 to 10, 1892. Small squares represent one-tenth of an inch.

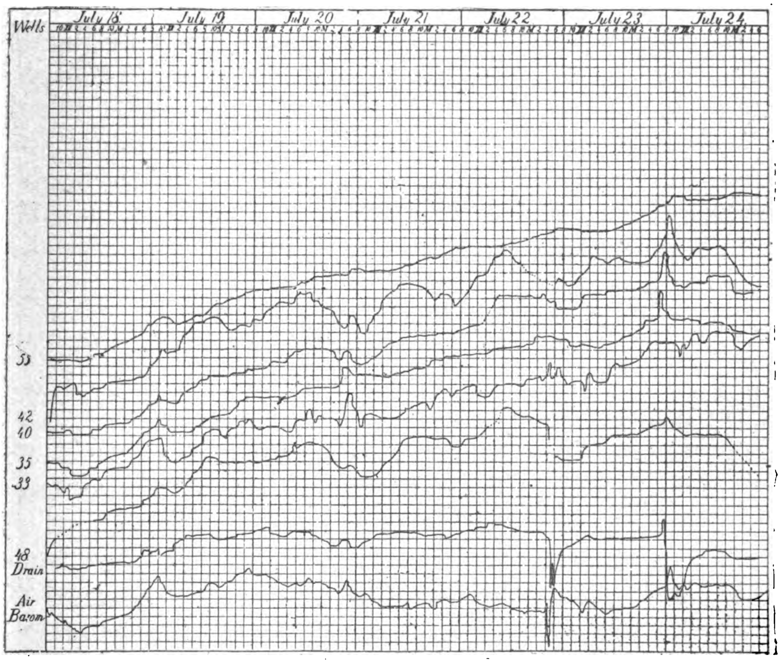


PLATE V.—Synchronous fluctuations in wells, drain, and air barometer July 18 to 24, 1862. Small squares represent one-tenth of an inch.

It will be seen from a study of these plates that nearly all of the marked sudden barometric changes are shown, in a greater or less degree, on nearly all of the wells. The long period barometric oscillations are usually recorded by the wells, but these are much more obscured by the percolation of rain into the ground and by the general lowering of the ground-water surface by subterranean drainage. That this should be so is plain, because it very often happens that, at a given well, the downward descent of the water-level, due to drainage, is exactly compensated for by the rise due to a fall in the barometer, and in such a case the tracing for that period will be horizontal, while in that of another well in which the water chances to be rising at the same time in consequence of percolation, the barometric effect will be added to that of percolation, so that while the first well shows no curve corresponding to that of the barometer the one for the second shows it in an exaggerated form. The evidence of the influence of long period barometric oscillations must therefore be sought, generally, in a variation in the mean rate of change in the fall or rise of the ground water surface.

It appears to be a general rule that the long period barometric oscillations, and perhaps all barometric changes as well, exert a greater influence upon the water of the deeper than upon the shallower wells, and this, too, should be expected from what has been said, because the deeper wells are less affected by local percolation into them and the reverse action which is a consequence of it.

SEMI-DIURNAL OSCILLATIONS IN THE LEVEL OF WATER IN WELLS.

It has already been pointed out that the water of wells exhibits a tendency toward diurnal oscillations, the water, as a rule, standing higher in the morning or else not having fallen as rapidly during the night. The continuous records obtained from the wells, from the spring and from the drains show very clearly, at times, that the level of water in the non capillary spaces in soil is subject to regu-

lar semi-diurnal oscillations, as a careful inspection of the various plates will prove.

To render these semi-diurnal changes more apparent, I have selected a week when there were no large barometric changes and have taken a well in which the water surface was nearly stationery so far as drainage and percolation are concerned. The week selected was that ending July 11, 1892, and the well was No. 33. Side by side with this the curve produced by the air barometer has been placed, and with it also that of the Richard barograph of the same date. The curve of the Richard barograph is magnified about six times and was constructed as follows: The record sheet was passed through the field of a compound microscope, provided with an eye-piece micrometer, and magnifying 43 diameters. The changes in the position of the barometric curve on the record sheet were measured at the crossing of each of the two-hour lines by bringing one end of the micrometer scale always to the lower side of a distance line and reading the distance to the under side of the barometer curve in divisions of the micrometer scale, and as fifty divisions of the micrometer just spanned the distance lines it was possible to read the changes very closely and to plot them on a large scale very accurately. The two barometric curves and that of the well are shown on the upper portion of Plate VI, where the coincident semi-diurnal changes are very evident on nearly every day of the week. It will be seen that there is a minor minimum falling from 9 to 11 p. m., and a major one falling from 7 to 10 a. m. On the same plate there have been plotted the curves of the same well for the two following weeks, and also that of the air barometer for the last week, and it will be seen, when these are all compared, that, while the more numerous short period barometric fluctuations tend to obscure the semi-diurnal ones, these are evidently there and in the same relative position with respect to time.

The 300-foot artesian well at Whitewater and the spring also show these same semi-diurnal fluctuations, but the long barometric oscillations were so great during the weeks when the records were kept that the semi-diurnal oscilla-

tions are much obscured by them, and there they appear to fall at about the same times of the day also as they do with the shallower wells at Madison.

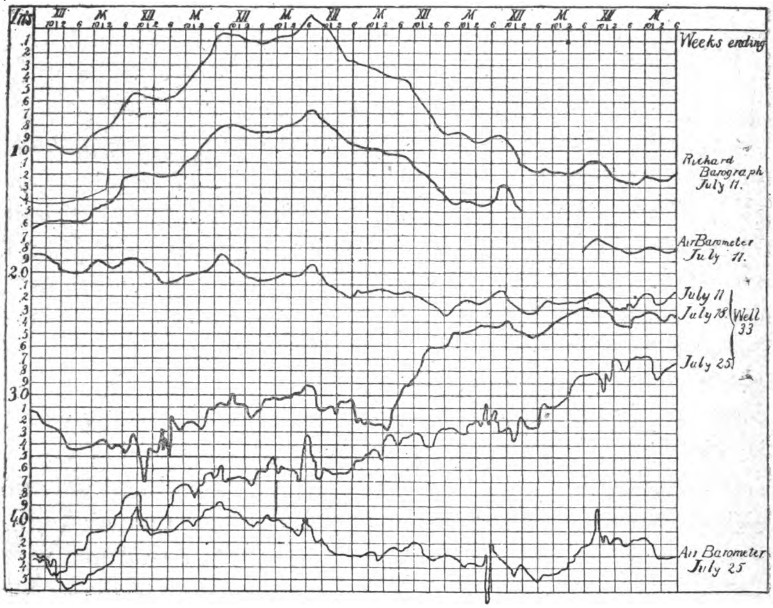


PLATE VI.—Semi-diurnal oscillations of the barometer and of water in wells.

I find in the Report of the Transactions of the British Association for 1883, p. 405, the following, under the subject—"On the Attractive Influence of the Sun and Moon Causing Tides, and the Variations in Atmospheric Pressure and Rainfall Causing Oscillations in the Underground-Water in Porous Strata." By Isaac Roberts, F. G. S.:

The investigations have been made at Maghull, which is an agricultural district about eight miles to the northeast of Liverpool, and relate to movements in the underground water of the Triassic rocks, which lie beneath the surface of the ground. The water in these rocks is by capillarity made to form an inclined plane toward the sea, which, at the point referred to, has its surface sixty feet above mean sea level. The water plane was shown to be in a state exceedingly sensitive to the following influences, namely, atmospheric pressure, lunar attraction, and solar attraction.

In order to determine the relative extent of these and other disturbing

influences upon the water plane, an artesian well was sunk in the Triassic rocks to a point below mean sea level and the rise and fall of a column of water sixty feet in height, freed from the friction in the rocks, was used as the means of registering these disturbances in the water plane, by using a mechanical combination of a float and drum, caused to revolve by clock-work, to trace a curve upon the diagram paper.

The curves show the extent, from moment to moment, of the atmospheric variations, and also the effects of the attraction of the sun and moon upon the water plane in producing oscillations in the first case and true semi diurnal lunar and solar tides in the latter case. The effects of rainfall were also shown on the diagram.

It was also shown that there were periods when all of the forces which have been named were in equilibrium, the water plane remaining in a state of perfect quiescence during those periods.

The statement to which attention is here called especially, is the one ascribing certain fluctuations in the level of the water in this well to both solar and lunar tidal disturbances. I have not, as yet, been able to learn whether the paper to which the above report refers has been published or not, and do not, therefore, know the character of the evidence upon which these statements are founded. There is certainly no unequivocal evidence presented by any of the curves obtained in the investigation here which would lend support to the view that a lunar tidal effect has been exerted large enough to be recorded by the instruments used. The apparently entire absence of any progressive change in the time of day at which the maxima and minina occur is the strongest evidence which can be presented against the view that a lunar influence is here recorded. There is, of course, nothing in the time relation which would disprove a solar tide; but if a solar tide is admitted to be recorded, there then appears no reason why, at times at least, a larger one should not also be recorded, having the proper time relations for the moon. Some of the wells at Madison, included in this study, are deeper than the one used by Mr. Roberts and extend below the level of Lake Mendota in the Potsdam sandstone. The still deeper wells at Whitewater also find their water in a porous sandstone, so that the only condition apparent, which is fundamentally different in the well of England, is the

close proximity of an oceanic body of water which is, itself, subject to tidal fluctuations. This being true, one is led to suspect that in case the wells in question do exhibit both solar and lunar tidal oscillations they, in some manner, may be a reflex of the oceanic tides.

We are told, however, that the well in question is some 8 miles distant from the sea and that the water "*is by capillarity* (the italics are the writer's) made to form an inclined plane toward the sea, which at the point referred to has its surface 60 feet above mean sea level." Now, were it true that the water is sustained in the well by capillarity to a height of 60 feet in the soil, which the writer knows of no sufficient evidence to prove, it is then required that a rise and fall of the ocean level permits capillarity to increase the height of the soil water when the length of the water column is diminished by the rise of the tide on the coast, but this implies that a force which is able to carry the water to a greater height in the soil is unable to retain it there after it has done so, for otherwise the level of the water in the well would not be affected.

If the oceanic tidal wave is transmitted to the well it would seem that it must be the result either of a direct shock or, what is much more likely, through a deformation of the rock strata by the loading and unloading of the coast.

It had occurred to the writer before reading the notice of Mr. Roberts' results, that in case the superficial strata of the earth are subject to any deformation by tidal stress, the unequal strength of the confining beds of an artesian basin, or the change of volume due to warping such beds, if of equal strength, must necessarily be made evident by a change of level in any column of water sustained by the hydrostatic pressure of such a basin.

The calculated magnitude of these disturbances and of the barometic and tidal loading and unloading of continents and their margins given by G. H. Darwin, had led me to anticipate, for the tidal effect, a very pronounced oscillation of the water-level or pressure in the deeper artesian wells having extended basins. If such oscillations do exist in any of the wells upon which the observations here

detailed have been made, they are so masked by the semi-diurnal oscillations just described, evidently not due to this cause, as to require a more critical registration and analysis of them than has been possible in this brief study.

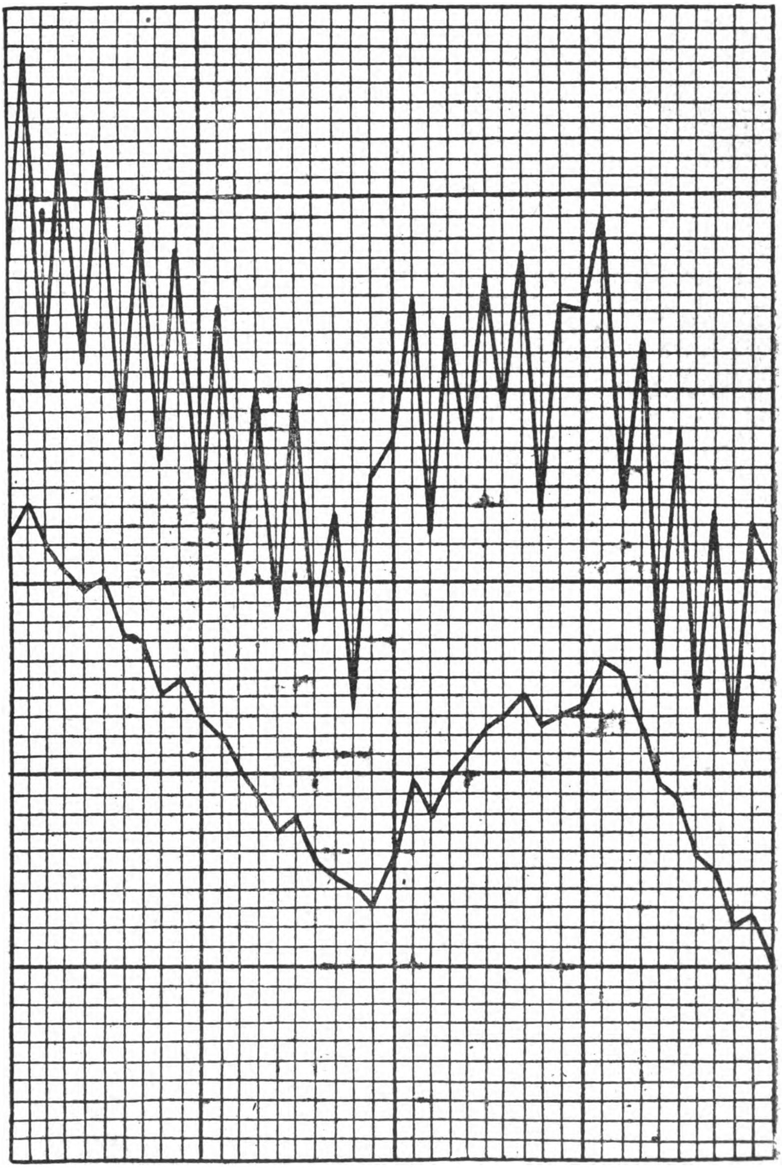


FIG. 46.—Diurnal oscillations in well 5, the lower curve showing fluctuations in well inside of well 5. Natural size.

INFLUENCE OF DIURNAL CHANGES IN SOIL TEMPERATURE IN PRODUCING CORRESPONDING OSCILLATIONS IN THE LEVEL OF GROUND-WATER.

The twice daily observations recorded on Plate I and referred to on page 155, show very clearly that in certain wells and at certain times there is a marked diurnal change of level in the ground-water surface. In Fig. 46 is given a section of Plate I, natural scale showing the diurnal changes in the level of water in well 5 during the days from July 18 to August 6, 1889. From this it will be seen that the water rose during the night and fell during the day to the extent of a full inch or more. The curve plotted below the one of larger amplitude shows the changes of level which occurred in the center of the same well and during the same time, the two sets of observation being simultaneous. The circumstances are these:

The ground-water level had fallen until well 5, now in question, was likely to become dry. In order not to lose the records it was deepened by boring a hole in the center and curbing it with sections of 5-inch drain tile in the manner represented in Fig. 47, which shows the two water surfaces, whose fluctuations are recorded in the last figure. The original well, having an inside diameter of one foot and a depth of 5.5 feet, was bricked up to within 2 feet of the surface and then finished with a section of sewer pipe, as shown in the cut, where the character and arrangement of the soil through which the well penetrated may also be seen.

The facts are, strange as it does appear, that under these conditions and in such close juxtaposition oscillations so unlike in their character as the two under consideration were produced simultaneously. The level of the water in the outer well oscillated so as to stand in the morning from .1 to .3 inch above the level of the water in the inner one and at night from .5 to 1.2 inch below that surface, and these differences were maintained with only the unglazed section of drain tile separating them. During the day, then, presum-

ably, water was flowing from the inner well over into the outer and larger one, while the fact that the water in the outer well rose to a height exceeding that in the inner one shows that some of that water at least must have come into the well from a level above the bottom of the outer well. As shown in Plate I, the large oscillations in this well became

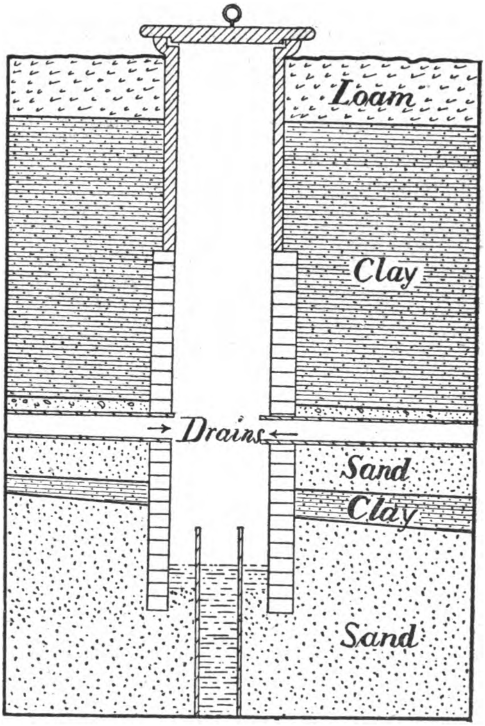


FIG. 47.—Construction of well 5, and the character of the soil through which it penetrates

very pronounced and constant only a short time before it became dry, and the inner well did not take up the marked changes in level after the water fell below the bottom of the original well. No other well of this series, although constructed in the same manner, showed such marked oscillations as this one. Referring again to Plate I, it will be seen that several other wells did show them, but that there is something apparently very capricious about the starting and stopping of these oscillations. Wells 45, 43, 41, and 40

took on these strong oscillations just after they had been deepened, while well 44 did so without being deepened at all. Wells 40 and 43 oscillated in this marked manner only a few days, while well 41 did so from August 3 until after the middle of September. From the 3d of September until after the 15th all the wells showed a tendency toward an increased diurna fluctuation. When these fluctuations were first observed in the fall of 1888, as already referred to—the one in the corn exhibiting the greatest oscillations, while the one in the stubble showed least, as represented in Fig. 19—it was then thought that these differences in the magnitude of the oscillations might be due to differences in the daily amounts of water withdrawn from the soil by vegetation. The observations of the following seasons showed that this could not be the chief cause of the difference, for then well 5 was on a blue grass sward with the grass cut short at the time the oscillations were most marked, while well 41, penetrating fallow ground, oscillated much more than did the wells on either side with corn growing about them. Another peculiar feature about these oscillations is the fact that during the years from 1888 up to the present time no such marked changes in level of the water were revealed by twice-daily observations taken in the morning and evening until past or near the middle of July, from which time there is an advance toward a maximum, occurring some time in August and then a dying away again until along toward the middle of October, when they again became inconspicuous.

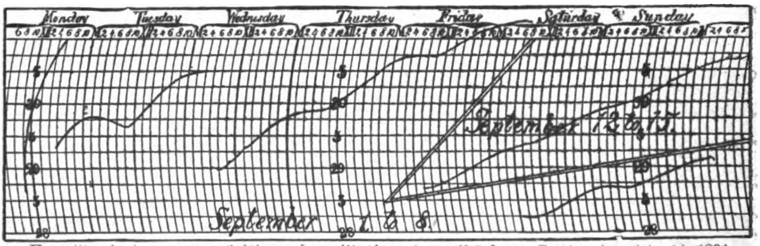


FIG. 48.—Dying away of Diurnal oscillations in well 5 from September 1 to 14, 1891.

In the fall of 1891 the improvised self-recording instrument referred to was placed upon well 5, September 1, just as the oscillations in question were beginning to die away,

and Fig. 48 shows these changes from September 12 to 14, when their amplitude had become almost inappreciable. In Fig. 49 are also plotted the curves for wells 42 and 44 and the drain from July 25 to 28, 1892, when these oscillations are beginning to become pronounced. It will be seen by referring to Plate V that these diurnal oscillations were beginning to be evident in the previous week.

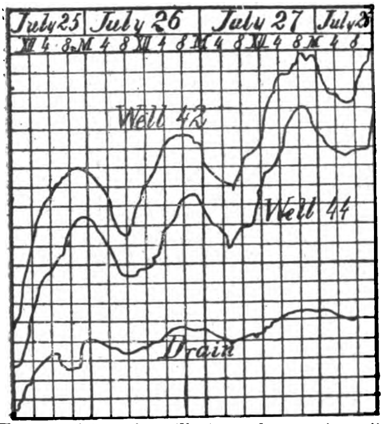


FIG. 49.—Diurnal oscillations of water in wells and drain due to diurnal chanees in soil temperature.

In the spring of the present year a galvanized iron cylinder 6 feet deep and 30 inches in diameter, provided with a bottom and water tight, was filled with soil, standing its full height above the ground in the open field. In the center of this cylinder and extending to the bottom, a column of 5-inch drain tile was placed and the soil filled in about it and packed as thoroughly as practicable. Water was poured into the cavity formed by the tile until it was full, and allowed to percolate into the soil so as to saturate it and leave the water standing nearly a foot deep in the well. When the water in this artificial well had become nearly stationary one of the self-registering instruments was placed upon it, the object being then to ascertain whether water thus circumscribed in a well would exhibit fluctuations at all analagous to those observed in ordinary wells, and the apparatus as used is shown in the engraving, Fig. 50. In order to avoid any complications due to percolation, the apparatus was provided with a cover which could be put on in times of rain and removed again during fair weather. The first records showed a small diurnal oscillation, and as the season advanced these increased in amplitude until finally the water rose in the well during the day of July 8 1.8 inch and fell during the the following night 1.84 inch.

After these diurnal oscillations had become so pronounced and so constant a series of thermometers were

introduced into the side of the cylinder, extending to different distances from the surface, and a record kept of the changes in the soil temperature; and the result of these observations was to show that the turning points in the water curve fell exactly upon the turning points of the temperature of the soil in the cylinder. When this fact was ascertained, to show whether the correspondence in the time of the two curves was due to a diurnal cause, other than temperature which had its turning point so related to those of the temperature as to cause the two to accidentally fall together, cold water was brought from the well and, with a spray pump, applied to the surface of the cylinder all around. The water was applied on a hot, sunny day just after dinner, when the water was raising in the well, and the result was an immediate change in the curve, the water beginning to fall in the well and turn the pen up. The water was then turned off, and the result of this change was to stop the fall of the water in the well, as shown by a change in the direction of the curve downward again. After the lapse of about another hour the water was again turned on, with the result first obtained, and again when the water was withdrawn the curve was once more reversed; a tracing of the curve obtained during these trials is represented in Fig. 51.

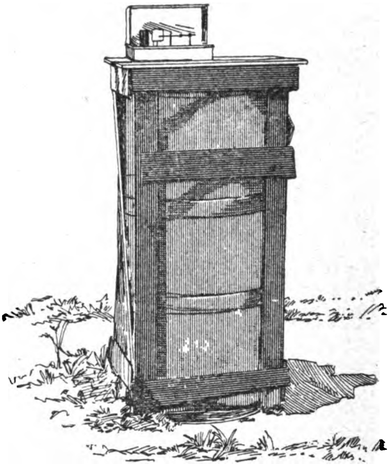


FIG. 50. Apparatus used in demonstrating the influence of temperature in producing diurnal oscillations of water in wells.

These experiments showed that there was a positive connection between changes in the soil temperature and changes in the movement of the water in the soil. Since the water left the well and entered the soil with a lowering of the temperature, it follows that the observed changes could not be the result of a change in the volume of the cylinder due to shrinkage and expansion, for the

movements of the water were in the opposite direction from what a change in volume would have produced.

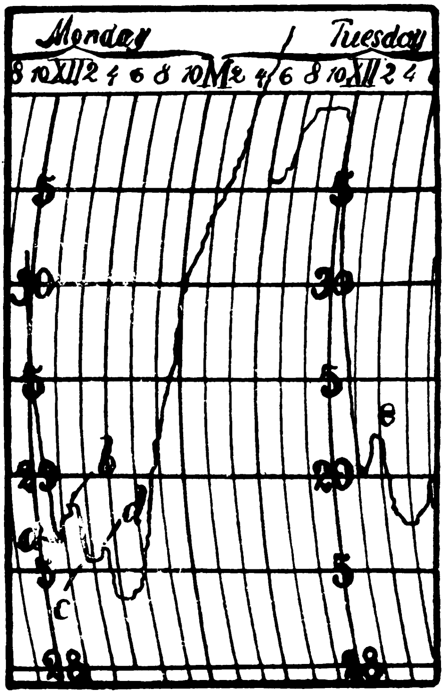


FIG. 51.—Changes in the level of water in the well in the cylinder produced by pumping cold water on the sides of the cylinder; a and c show times of applying the water; b and d show when the water was withdrawn, and e shows curve produced by sudden thunder shower.

The quantitative relation existing between the movement of the water in the soil and the change in temperature is expressed below:

Date.	Mean temperature of soil.		Amount of change in temperature.		Amount of change in water.	
	A. M.	P. M.	A. M. to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.
	° *C.*	° *C.*	° *C.*	° *C.*	*Inches.*	*Inches.*
July 7	19.4	26.3	+ 6.9	....	+ 2	....
July 7-8	26.3	19.4	....	— 6.9	....	— 2
July 8	19.4	23.5	+ 4.1	....	+ 1.8	....
July 8-9	23.5	20.7	....	— 2.8	....	— 1.84
Mean	....	....	5.175° *C.*		1.91 *in.*	

Here we have a mean change in water-level amounting to .369 inch for each degree C.

Taking the period from June 6 to 9 we have—as below—

Date.	Mean temperature of soil.		Amount of change in temperature.		Amount of change in water.	
	P. M.	A. M.	A. M to P. M.	P. M. to A. M.	A. M. to P. M.	P. M. to A. M.
	°C.	*°C.*	*°C.*	*°C.*	*Inches.*	*Inches.*
June 6...	17.3	22.7	+5 4	....	+1.22	....
June 6-7...........	22.7	18.3	....	— 4.4	....	—1.17
June 7......... ...	18.3	20 5	+2.2	....	+ .72	....
June 7-8...........	20.5	17.4	....	— 3.1	....	— .87
June 8.	17.4	20.5	+3.1	....	+ .87	....
June 8-9...........	20.5	17.3	....	— 3.2	....	—1.1
Mean..........	....	....	3.57°*C.*		.99 *in.*	

In this case we have a mean change in the water-level of of .276 inch for each degree C. The cavity into which the water percolated and from which it was again withdrawn with each change of temperature had a diameter of 5 inches, so that the amount of water which left the soil and entered the well was about 6 cubic inches for each degree C. I suppose it was also true that the non-capillary spaces in the soil above the water level in the well were also filled to a certain depth and emptied again, so that the total movement of water in the circle of soil 30 inches in diameter was something more than the 6 cubic inches stated above.

In another cylinder, 10 feet long and 1 foot in diameter, standing in a large silt well 6 feet deep and 4 feet in diameter, the water rose and fell daily between July 15 and 18 an average of 3.33 inches as measured by the change of level of water in a glass tube communicating with the bottom of the cylinder. And, in this case, I suppose the surface of the ground-water in the cylinder rose and fell each day through the mean distance stated. How great the diurnal change of the soil-temperature may have been in the cylinder is not known, but as the cylinder stood below the level of the ground surface in a cavity

into which water from the drains was discharging, I suppose that the diurnal range in the cylinder could not have exceeded 2° or 3° C. below the surface of the ground.

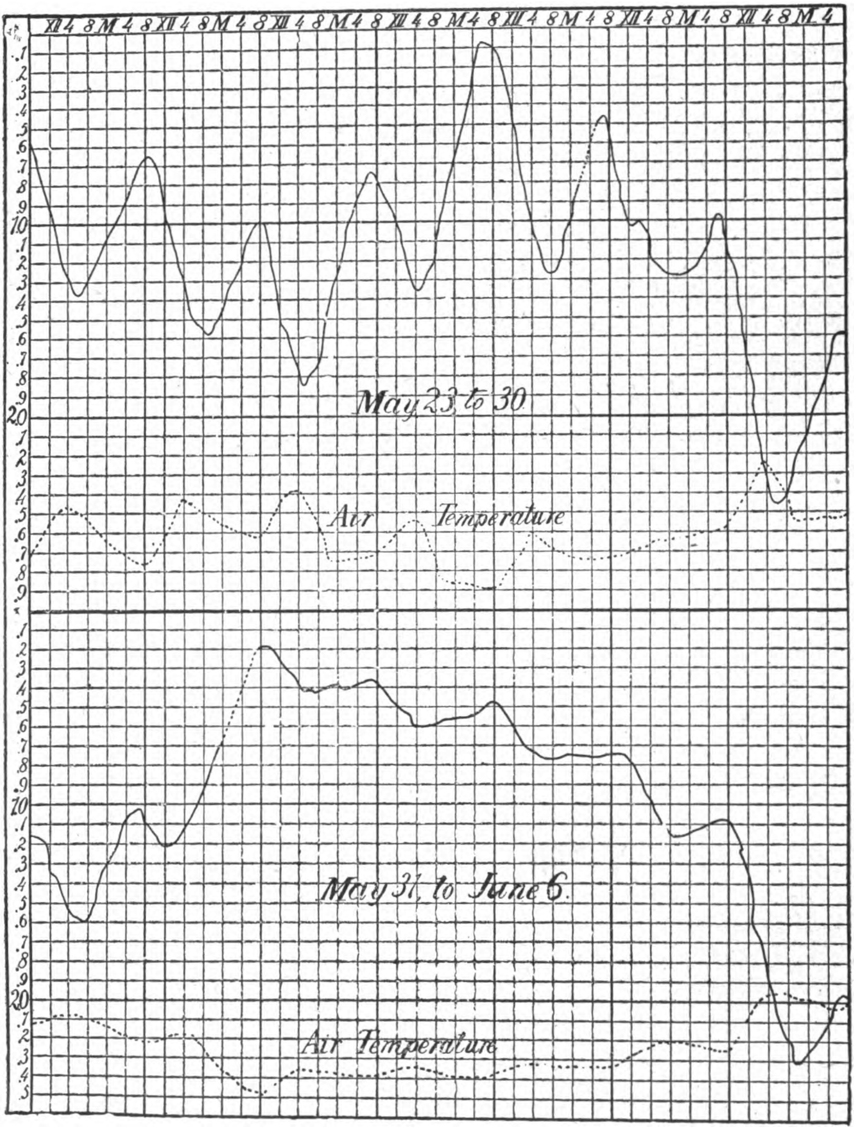


FIG. 52.—Diurnal changes in level of water in the well in the cylinder from May 23 to June 6, 1892, and the corresponding air temperature for the same period.

In Fig. 52 the changes in the level of the water in the well in the cylinder are plotted for two weeks, and side by side with these is plotted the tri-daily air temperature as observed at Washburn Observatory. Here it will be seen that there is apparently no evidence of barometric fluctuations, but a close agreement with the temperature curve.

There is, therefore, in my judgment, no ground for reasonable doubt but that these diurnal oscillations of the water level in the two cylinders were due to an oscillation in the intensity of the capillary power manifested in the soil contained.

To ascertain whether temperature changes in the soil of the field produce a manifest movement of the soil water, it is required to show, in the first place, diurnal oscillations which are evidently not barometic, and second, that the turning points of these curves are on the turning points of the soil temperature in the zone in which the movement of the water takes place. That there are diurnal oscillations evidently not related to any of the observed barometic changes of pressure, has been pointed out, and it remains to show that these do or do not fall into unison with the diurnal temperature curve.

My first effort in this direction was to ascertain whether any probable change of temperature in the wall of the wells was capable of producing the amount of movement observed, and to do this an apparatus was constructed and set in the soil, consisting of a double walled cylinder taking the place of the tile in the well, and a current of warm water, having a temperature of from 70° to 90° F., was kept circulating through it during three consecutive hours on three different days. One of the one-day recording instruments was used to register the fluctuations in the level of the water in the well. There was in no one of these trials any change in the curve which appeared to have any connection with the time of beginning or closing of the experiments, and yet the changes in the temperature of the walls of the well must have been greater than the diurnal range due to atmospheric changes of temperature. I then

buried bodily a thermograph, first at a depth of 5 feet and then at a depth of 18 inches. The degree lines in this instrument were too close to detect more than the slightest diurnal change at the greater depth, but at 18 inches the diurnal range was appreciable but could not be measured very accurately, and as the instrument in its box occupied a space of 9 inches, the temperature change recorded could not be located at any definite plane. I then constructed a thermometer, in the form represented in Fig. 53, out of 1¼ inch gas pipe 18 feet long, and filled it with alcohol, which was made to act upon a plug of mercury in the bend of the tube, the latter moving a float which was attached to one of the recording instruments used on the wells. Only an approximate calibration of this instrument was attempted, and was done by placing a soil theremometer in contact with the center of the tube in the soil and keeping a record of its changes as checks upon the other.

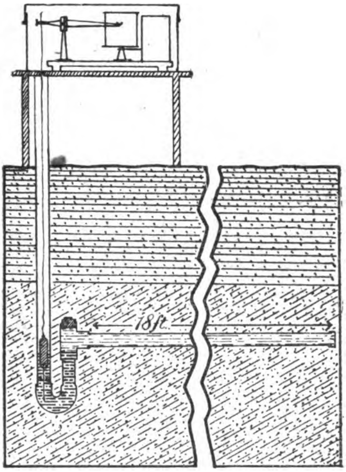


FIG. 53.—Construction of new form of self-recording soil thermometer.

The curve produced by this instrument, placed 18 inches below the surface, and that of a thermograph sheltered at a height of one foot above the ground at the place, giving the air temperatures for the same period, are shown in Fig. 54. Here it will be seen that the soil at 18 inches below the surface is subject to a diurnal oscillation amounting to about 1° F., and that the lowest temperature in the soil occurs, at this level, a little after noon and the highest a little after midnight.

We have no observations, as yet, which definitely settle from what level the water, which produces the rise in the well, comes, but I know no reason for supposing that the chief part comes from above the 18-inch level. If the water

comes from below the 18-inch level the temperature changes which effect its movement should be expected to lag still more behind those of the air and so bring the highest temperature, not a little after midnight, but at some later interval. Referring to the figures showing the diurnal oscillations in question, it will be seen that the lowest points in the curves, which represent the highest water in the well, and which correspond to the warm epochs in the soil cylinder referred to, occur at from 6 to 8 in the morning and, as the level of the water in the wells and that which discharges into the drain is more than twice the depth of the soil thermometer below the surface, there appears no great improbability that the lagging of the temperature wave is entirely sufficient to cause the percolation into the wells to occur at the time at which the curves show that it does take place.

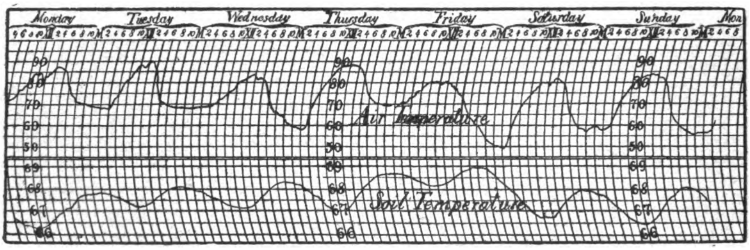


FIG. 54.—Diurnal changes in soil temperature 18 inches below the surface, and corresponding air temperature for the same period.

The reason for the absence of oscillations during the spring and early summer due to changes in the soil temperature may not at first be apparent, nor can one be assigned with any degree of assurance until we have obtained satisfactory continuous records of soil temperature at various depths below the surface. Still, observations do show that the temperature does progress downward slowly, and while the surface soil is so full of water, which is being evaporated from the surface rapidly, there would be relatively less energy left daily for transmission downward. Besides this, the zone of soil in which diurnal oscillations are appreciable, we have reasons to expect is progressively increasing

during the whole season of increasing temperature, and future continuous records may show that below even a very shallow depth there are, early in the summer, no measurable oscillations of this character.

There is another possible cause of increasing diurnal oscillations later in the season which does not exist in the spring. I refer to the extension and occupancy of the soil by the roots of growing vegetation. Since large volumes of water are carried to the surface in increasing quantities as the season advances, and since sap from the stems and leaves bathed in the warm air is carried downward into the ground to feed the roots, we may expect a certain quantity of heat to be transported below the surface and to considerable depths in this manner, and this would have an increasing effectiveness later in the season as the water is withdrawn from the soil, for such withdrawal must very materially diminish the mean specific heat of the soil, thus allowing the same number of heat units to produce a greater change in temperature.

EFFECT OF INCREASING SOIL TEMPERATURE ON THE GENERAL HEIGHT OF THE GROUND-WATER SURFACE.

Since the water-holding power of soil is decreased by an increase of temperature it follows that the seasonal rise of temperature in the ground must have the effect of increasing the rate of percolation and of enabling some water to reach the ground-water level which, during the earlier season, would be retained in the soil by capillary action This effect, therefore, must tend to hold the level of ground-water above what it would otherwise occupy. The same cause would also tend to decrease the per cent. of water in the soil below the surface and cause it to appear to be drying out by capillary action upward, when in reality the drying was the result of percolation downward, due to a rise in the soil temperature.

INFLUENCE OF CHANGES IN SOIL TEMPERATURE ON UNDERGROUND DRAINAGE.

If it is admitted that an increase in soil temperature decreases the water-holding power of the soil, it should be

expected that under suitable conditions drains would show a diurnal variation in the rate of discharge, due to diurnal changes of temperature. The curve produced by the drain gauge, which is shown in the figure, with those of the wells exhibiting the marked diurnal oscillations, appears to be in perfect accord with them so far as the diurnal oscillations are concerned, and hence indicates that there are or may be diurnal changes in the rate of flow of water from the ground, due to temperature changes.

During some laboratory studies conducted at this station, in which the writer attempted to ascertain whether the presence or absence of salts influenced the rate of flow of water through soil, he found that the apparatus was so extremely sensitive to temperature changes that no concordant results could be obtained until the whole apparatus was put under complete control so far as changes in temperature were concerned. To illustrate this influence the following results may be cited: Starting with the apparates filled with a coarse sand and at a temperature of 9.01° C., the flow =6.153 grams per minute; at 9.23° C., the flow =6.27 grams per minute; at 9.38° C., the flow =6.384 grams per minute; at 12.6° C., the flow =7.046 grams per minute; at 23.8° C., the flow =9.014 grams per minute; at 32.46° C, the flow ‖ 10.54 grams per minute.

While it is likely that a part of the increase in the rate of flow through this sand was due to the fact that the coefficient of expansion of the walls of the apparatus and that of the sand were not the same, yet the differences in the rate are too large to be accounted for completely in this manner.

In case it is true that changes in the temperature of soil do affect the rate of flow of water through it, it should be expected that the configuration of the general ground-water surface would change as a consequence of this temperature influence, for under the lower grounds, where the summer temperature penetrates more quickly to the zone in which the water is flowing toward drainage outlets, the resistance to flow would be decreased and the surface of ground-water

would fall more rapidly as a consequence than it would under the higher and colder ground.

Then, again, under the reversed conditions of winter, when the low lands are colder at the level of ground-water than under the higher land, the resistance to flow would be increased and the relatively more rapid drainage from the higher lands would tend to raise the water surface under the colder low lands above the normal, and hence to develop, toward spring, an attitude of the ground-water surface approaching more nearly to horozontality than is normal to the summer season.

We have shown that the diurnal variation in the temperature of the soil at a depth of 18 inches below the surface is, at the date of writing, only about 1° F., and that it is probably less than this at the depth of the wells and drains, and yet the continuous records obtained appear to show that such small changes of temperature are effective in modifying the rate of discharge of water into the drains as well as upon the height of water in the non-capillary spaces of the soil. Now, if the movements of water through the soil are thus sensitive to temperature changes it follows that in two countries where the mean soil temperatures vary to a considerable extent, the effectiveness, capacity, proper depth, and distance apart of tile drains may be found to to materially differ.

TEMPERATURE TIDE OF THE GROUND-WATER SURFACE.

It follows, from the observations here recorded, that in all places where the diurnal oscillations of soil temperature reach the ground water this surface is by it subjected to an ebb and flow vertically over the surfaces of the soil grains, which reaches upward possibly even through the zone of soil containing only hygroscopic moisture; for if the thickness of the film of water which can be borne by the soil grains varies with the temperature, there may be a progressive thinning and thickening of this film as the temperature rises and falls, and, if this is true, the soil grains are subjected to an exchange of water upon their

surfaces throughout a deep zone, which must influence greatly those disintegration processes which contribute so much to the fertility of soils and to the leaching of them. Even if this ebb and flow is confined to a zone extending but a foot above the level where the non-capillary spaces in the soil remain full, the sum total of its effects must still be very great.

SEISMIC OSCILLATIONS OF THE GROUND-WATER SURFACE.

One of the surprising observations made during this study is that a heavily loaded moving train has the power of disturbing the level of water in the non-capillary spaces of the soil, but in just what manner this is brought about is not easy to see. The observed facts are these: While the self-registering instrument was upon well 48 it was observed that there were frequent records of sharp, short period curves shown upon the sheet, which at first were supposed to be the result of accidental jars which the instrument sustained; but the frequency of their occurrence and the fact that they were always dependent from the other curve, led to a closer scrutiny of them and their final

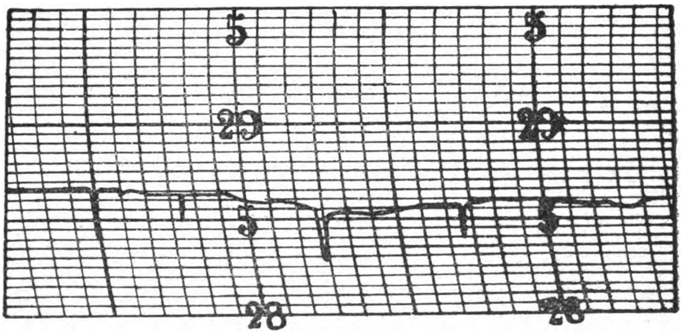


FIG. 55.—Changes in level of water produced by moving train.

association with the movement of trains past the well. On the eight-day instrument these fluctuations were shown as single dashes, but with the one-day form the curve was open and having the character shown in the tracing, Fig. 55. The well in which these disturbances occur is situated about 140 feet from the railroad track, and has a depth of

40 feet. It is tubed up with 6-inch iron pipe to the sandstone, 37 feet below the surface, and the water has a mean depth of about 20 feet in it.

The strongest rises in the level of the water are produced by the heavily loaded trains which move rather slowly. A single engine has never been observed to leave a record, and the rapidly moving passenger trains produce only a slight movement, or none at all, which is recorded by the instrument. The figure shows the curve to be produced by a rapid but gradual rise of the water, which is followed by only a slightly less rapid fall again to the normal level, there being nothing oscillatory in character indicated by any of the tracings nor observable to the eye when watching the pen while in motion. The downward movement of the pen usually begins when the engine has passed the well by four or five lengths, and when the pen is watched it may be seen to start and to descend quite gradually, occupying some seconds in the descent. The actual amplitude is one third of that shown in the cut, which represents about the average occurrences, and these disturbances are not peculiarities of the present season when the groundwater surface occupies a higher plane than it has during the three years past, for the records of last year, which were procured with the improvised instrument to which reference has been made, bear evidence of the same disturbances produced then.

The manner in which a train moving across the groundwater surface lying 17 to 20 feet below can effect such changes as the instruments have recorded is not at once apparent, especially when it is observed that the site of the records is 140 feet distant from the railroad track. The first explanation which suggests itself is that the short period shocks which the earth sustains in the transit of the train are transformed into a wave of long period which is propagated radially from the center of the disturbance and, reaching the well in its course, produces the record there obtained; but such an explanation appears to be rendered inadmissible because there is one single rise and fall, with no trace whatever in the curve of a repetition, as a true

wave implies. A more probable hypothesis perhaps is that the mass of the train in its transit by the well depresses the earth bodily, causing it to sink into the ground-water more deeply and thus displace it laterally, causing it to rise under the surrounding area; but if this is true, and the displacement of the water has occurred equally in all directions, a rise of one-tenth of an inch at the well, 140 feet distant, means a downward displacement at the track amounting to something more than this, apparently twice that amount at least.

So far as the character of the curve and the method of recording it are concerned it would be equally admissible to suppose that the ground, as far away as the location of the instrument, was bodily depressed so that the recording apparatus moved downward, rather than that the surface of the water in the well moved upward, in producing the curve; but on this hypothesis the amount of earth moved seems enormously great when compared with the inertia of the train which prodaced the rise of water in the well. Again, it may be urged that the movement at the well which produced the record was the result of an upward thrust of the ground-water surface and a down-throw of the soil in the same place, so that the total movement in either case may not have exceeded .05 of an inch.

As still another alternative, it may be urged, that, either by compression of the zone of capillarily saturated soil lying just above the ground-water surface, or by its frequent recoils from the shocks imparted by the moving train, some of the capillary water is forced out of the soil and made to raise the mean level of the ground-water, thus augmenting the head so as to cause the water to rise in the well. But to raise a float one-tenth of an inch at a distance of 140 feet implies a dislodgement of capillary water and an augmentation of head seemingly too large to be produced by the most heavily loaded train.

Since such changes as result from the movement of a train over the ground affect the level of the water in it to such an extent as to be susceptible of measurement in the manner described, we may, perhaps, expect to find that the

ground-water is sensitive to seismic disturbances and that the method here used, or a modification of it, is capable of rendering valuable information in volcanic districts regarding earth-tremors due to such causes. Indeed, the extreme complexity of some of the curves obtained here, and more especially of those obtained at Whitewater, of which tracings are given, implies, either that the barometic oscillations are much more frequent and of wider amplitude than we are accustomed to think, or else that the earth here is subject to tremors which may be recorded by fluctuations in the changes of level in the ground-water surface.

THE MECHANICAL ACTION OF BAROMETRIC CHANGES IN PRODUCING FLUCTUATIONS IN THE LEVEL AND DRAINAGE OF GROUND-WATER.

The evidence now at hand is insufficient to show, in a satisfactory and conclusive manner, just how changes in atmospheric pressure produce those changes in the level of the water in wells and in the rate of flow from the ground which have been shown to be closely associated with them. Unless some overshadowing influence is in operation at the same time, a rise in the barometer is very nearly coincident in time with a fall of the water in wells and with a diminished rate of discharge of water from the ground, and *vice versa.*

There are two radically different methods of action, by either of which we may suppose the phenomena in question are brought about through changes in atmospheric pressure. In the first place, it may be supposed that the general level of the ground-water surface is depressed or elevated bodily, as the case may be, by barometric changes, the loading of air upon a region depressing the ground-water surface of that region and the unloading of it permitting the level to be partly or wholly restored again. In the second place it may be supposed that, through an unequal permeability of the soil above standing water in the ground, the changes in atmospheric pressure are more quickly felt by the water surface at some points than at others, and as a consequence,

a rising barometer will cause the water to be depressed in wells and in open soils, the water raising into both the capillary and non capillary space of the adjacent less permeable areas, while a reduced air pressure would permit the confined air in the soil of the more impermeable regions to react and force the water into wells and drains, thus producing the phenomena associated with the falling barometer.

If a high barometric area develops over the west Atlantic ocean while a low area has formed upon the eastern portion, maintaining a difference of pressure of one inch, the ocean surface, as a result of this unequal loading, will be deformed to the extent of 1.13 foot, the water-level on the west falling, while that upon the east rises through one-half of this distance; so if we suppose a continental ground ground-water surface in a state of drainage equilibrium to be similarly circumstanced, its surface would be, in a like manner, deformed, and as a result of this deformation the water would stand higher in the wells and discharge more rapidly from the springs and drains of the low-pressure area while the converse would be true under the high area.

*If Mr. G. H. Darwin is right in his estimate, that if the barometer rises an inch over an area like Australia the load is sufficient to sink the continent two or three inches, and that the tides, which, twice a day, load the shores of the Atlantic, may cause the land to rise and fall as much as five inches, there appears no physical reason why, the ground-water surface being more mobile than the rigid earth, and at the same time capable of moving through its interstices, should not suffer a deformation greater than that of the land itself when subjected to a similar load. If a horizontal canal be conceived to span a distance of two thousand miles and to lie above the general drainage plane so that water might discharge from opposite ends through gates of equal capacity, it is evident that, were a low barometric area to rest upon one end, the water would discharge from that gate at a rate exceeding the average while at the opposite gate the rate of discharge would be less than the

*Nature, Vol. XI., page 367.

mean. In like manner, if it is possible for atmospheric changes to depress or raise the ground-water surface in the vicinity of a system of tile drains, the water would flow more or less rapidly from this system according as the region was under the influence of a high or low barometric pressure.

It has been shown on a preceding page that the mean fall of the ground-water surface during times of rising barometer, as estimated by changes of level in wells, was .224 inch daily, while during times of falling barometer the mean fall was only .001 inch per day. Such a relation as this should be expected to exist if barometric changes are capable of affecting the general level of ground water in the manner here under consideration. Then again, in the case of the well in the galvanized iron cylinder, Fig. 49, in which the influence of temperature changes was shown, but which was constructed for the purpose of ascertaining whether or not the barometic changes were thus local in their effects, the curves no where show changes which can be ascribed to barometic influence, and this is what should be expected if the fluctuations are due to oscillations of the general ground-water surface. It is evident, however, that neither of these facts can be cited as lending much support to the view.

Turning now to the second hypothesis, the following conditions furnish the foundation for it: The condensation capacity of water for air varies with the pressure to which it is subjected, and, this being true, atmospheric changes are capable of affecting the volume of free air in the soil. It has been shown elsewhere in this paper that saturated and nearly saturated soils, especially those of fine texture, are nearly or quite impermeable to air under atmospheric changes of .1 of an inch. The capillarily saturated soils under field conditions possess both capillary and non-capillary spaces which contain air.

Under these conditions it may be assumed that when an area of low barometer passes upon a given district the equilibrium between the confined gases and capillary tension is destroyed, and by the expansion of the air escaping

from the water and that which exists in the capillary and non-capillary spaces of the soil above the ground-water level capillary water is forced out into the wells and into drainage channels, and thus increases the underground drainage for the time and the height of water in wells and in soils to which the air has free access. Then, when the barometic conditions are reversed, the permanent rarefaction which the soil-air has sustained through the withdrawal of water, and air as well, from the interstices of the more impermeable soil permits the increased barometic pressure to force the water from the well back into the passageways from which it came and thus lower the water-level in the well; then, too, in the case of springs and drains, if the water is flowing from more or less impermeable beds an increase of pressure would increase the resistance against which the water was flowing from the soil, while a decrease of pressure would amount to the same thing as giving the water a steeper gradient.

This hypothesis appears much more applicable to the very short period fluctuation, which the records so often show, than it does to those which are more gradual and involve the movement of so much larger volumes of water, as in the case of the spring at Whitewater, which continued to flow under an increased head for days in succession with a falling barometer, producing a curve very nearly concentric with that of the barometer as far distant as Madison. It should be stated also in this connection that the barometric change of level in wells bears no definite relation to the diameter of the well into which the water percolates, the rise being very nearly or quite as great in a well 4 feet in diameter as it is in one 5 inches in diameter, and yet it would seem that, if the water is drained out of the soil locally, the larger the well the slower its level would change. The difficulty may perhaps be satisfactorily met by supposing that the positive or negative gaseous tension reacts vertically chiefly upon the general ground water surface, causing it to rise and fall in a considerable measure bodily.

CAUSE OF TEMPERATURE OSCILLATIONS IN THE LEVEL OF GROUND WATER.

The amount of water which has been shown to leave the capillary spaces of the soil with an increase of temperature, and to return to them again when the changes are reversed, is so great as to make it difficult to understand how a simple diminution of the surface tension of the soil-water is capable of producing the whole movement, and has led the writer to suspect that possibly the expansion of the soil air contained in the capillary spaces of the soil, which is very nearly saturated, may, by its change of volume with change of temperature, account for a portion of the changes observed.

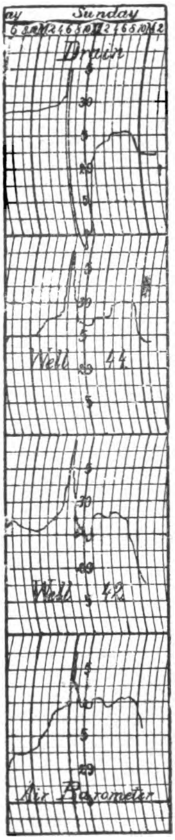


FIG. 56.—Curves due to instantaneous percolations after rains.

INSTANTANEOUS PERCOLATION AFTER RAINS.

It has been mentioned, in referring to the laboratory experiment relating to the distribution of capillary water in long columns of soil, that upon adding water to a column of coarse saturated sand, but which had ceased to percolate, the water began flowing again as soon as more was added to the surface. In this case the water which percolated at first was not that added to the surface, as was proven by the fact that in a short time the percolation ceased but only to begin again several hours later. The same fact I have observed in the field, and in Fig. 56 are produced the curves obtained with three of the self-recording instruments at one of these times; two of them on wells and one upon a drain. On the morning of th July 24 a sudden shower came from the north or west, and just as the black clouds were approacning, apparently about 20° above the horizon, the barometer began suddenly

to rise and continued to do so until a few minutes after the rain began, when it fell almost as suddenly to .05 of an inch below the starting point. On going to the wells and drains in less than 10 minutes after the shower of 15 minutes' duration had ceased, I found that the water had raised and was flowing so much more rapidly from the drain as to oblige the pen to be reset. The curve from the drain shows very conclusively that an increase in the discharge had occurred which persisted after the barometric change had passed.

These cases of sudden percolation I believe to be due to hydrostatic pressure which the water, falling upon the surface so rapidly as to close the air passages, exerted through the soil air upon the ground-water below.

PERCOLATION THROUGH FROZEN GROUND.

There appears to be a quite general impression that while the ground is frozen there can be little or no percolation through it. This is so far from being true that, during three consecutive winters, at times of sudden thaws or winter rains which melted considerable snow, the system of drains on the Experiment Station farm has discharged water so rapidly into the big silt well, No. 25, Fig. 21, that a 6 inch tile drain 560 feet long was only able to carry away the water brought to it when it had a fall of over 2 feet and a head in the well of nearly 4 feet. Not only has the water been observed to find its way into the drains through the frozen ground, but also into the shallow wells. During these times the water appears to find its way into the ground through shrinkage cracks, through perforations made by earth worms, and does so without apparently contributing very much to the surface 3 feet of soil. These facts are significant in the bearing they have upon the practice, now coming to be so general, of spreading farmyard manure upon the field during the winter. I would not here urge that these observations should disparage the practice, but that the matter is one which merits careful consideration in the study of the advantages of winter manuring.

SOME DIRECTIONS IN WHICH FURTHER STUDY IS NEEDED.

It should be at once apparent, in a subject possessing the extreme complexity of the one under consideration and presenting so many aspects of economic and scientific interest as does the movement of rain after it has penetrated the ground, that the observations herein presented can only be regarded as of the nature of a preliminary reconnoissance of but a small portion of a field in which our exact knowledge is relatively very limited.

A careful and detailed study of the movements of ground-water ought to supply very important knowledge bearing upon the contamination of drinking waters and the spreading of certain classes of contagious diseases, and thus help to place the water supply for both urban and rural purposes under better sanitary conditions.

Every advance which is made toward the increase of yield per acre necessarily means an increased demand for water, so that market gardeners even in Wisconsin and Illinois, where both the annual and summer rainfall is relatively large, are turning their attention toward providing suitable means for irrigation; and a rapid and economical advance in this direction demands a much more thorough knowledge of the movements of underground water than we at present possess.

In the utilization of natural subirrigation, to which reference has been made, and in the reclaiming of swamp lands for agricultural purposes, which must be of growing importance in the immediate future, there is imminent need for new knowledge in the same direction.

Before we can understand the full significance and extent of the movements of underground water, it will be necessary to have synchronous observations covering, not only considerable intervals of time, but also extended areas as well, and available contributions to our knowledge should be expected if improved forms of self registering apparatus for recording the changes in the level of ground-water were to be set up at many meteorological and experiment stations; and since the soil-water has been shown to be so sus-

ceptible to movements resulting from small barometric and temperature changes, there should be forms of self-recording soil thermometers more sensitive than any now available, and barographs which are capable of recording much smaller changes of pressure than most existing instruments do. It may be that a barograph constructed on the principle of the air barometer described in Fig. 41, but using a fixed oil instead of water, filling the chamber with chemically dried air and burying the whole more deeply in the ground, where the diurnal changes of temperature would always be very small, would answer the needs of such a study.

If the movements of ground-water generally even approximate those which the observations here recorded appear to indicate, a fuller understanding of them must shed much light upon those metasomatic changes which are of such great importance in geologic processes and in the origin and formation of metalliferous deposits.

Then again, if tidal fluctuations do really exist in the ground-water, as Mr. Roberts has affirmed, and if it is sensitive to seismic disturbances, as the observations here recorded in regard to the moving train suggests, a study of the movements of ground-water may be expected to contribute much toward an understanding of the nature, extent, and effect of the movements of the solid portions of the earth, whether they are due to stresses originating in extra-terrestrial causes or geologic or meteorologic shiftings of loads upon the earth's surface.

DIRECTIONS FOR USING THE BABCOCK MILK TEST.

S. M. BABCOCK.

This test was first described in bulletin No. 24 issued by the Wisconsin Agricultural Experiment Station in July, 1890. A description of it was also printed in the Seventh Annual Report from this Station, which appeared early in 1891. The demand for these publications, growing out of the extended use of the test by dairymen and breeders in all parts of the world, was so great that the editions were soon exhausted and bulletin No. 31, giving fuller information regarding the use of the test, was issued in April. 1892. The entire edition of this bulletin, comprising 10,000 copies, having been exhausted, a revised edition was published in July, 1893, as bulletin No. 36, and it was considesed best to reprint the same in the present report, so that a description of the test may be accessible to all who preserve our reports.

DESCRIPTION OF THE APPARATUS.

1. *Test Bottles.*—The form of the test bottles used in this test is shown in Fig. 57. They should be made of heavy glass and should contain, up to the neck, not less than 40 c. c. Each division of the graduated scale upon the neck represents .04 c. c. Five of these divisions are equivalent to one per cent. of fat when 18 gms. of milk are used in the test, it being assumed that the specific gravity of the butter fat, at the temperature at which the reading is made (about 120° F.), is 0.9. The graduation extends from 0 to 10 per cent. which is sufficient for all ordinary tests of milk. When it is desired to determine the fat in cream a longer scale is required, if the same quantity is taken for the test. To increase the length of the scale sufficiently for this pur-

pose with bottles of the usual form is impractical, as such bottles would not only necessitate extra care in filling and cleaning, but would require a special machine for whirling.

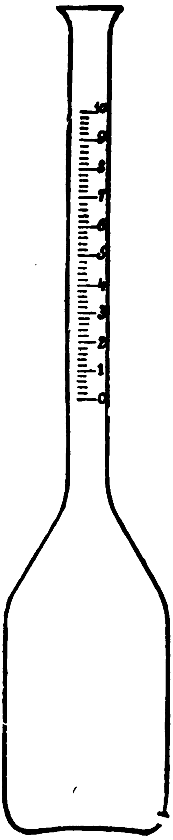


Fig. 57.

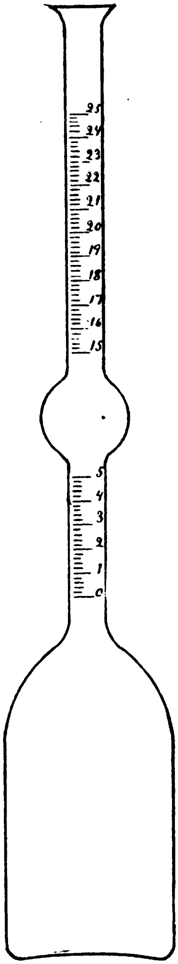


Fig. 58.

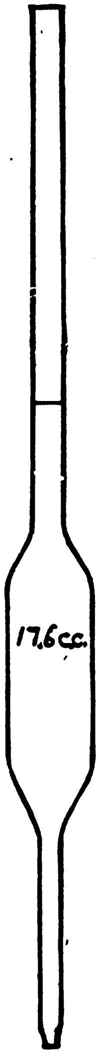


Fig. 59.

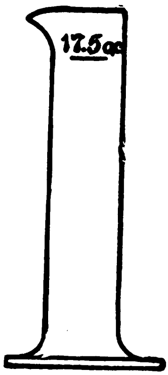


Fig. 60.

This difficulty has been overcome by the test bottle shown in Fig. 58, devised by Mr. J. M. Bartlett* of the Maine Agricultural Experiment Station.

*Bulletin 3, Second Series, Maine Agricultural Experiment Station.

This bottle differs from the regular test bottle in having a bulb blown in the neck, the graduation commencing below the bulb, which holds 10 per cent. With this bottle cream up to 23 or 25 per cent. of fat may be tested in the same manner as milk.

Parties ordering bottles of this kind should designate them as cream test bottles No. 1.

In creameries where skim milk is to be tested, a few bottles containing double the amount of those mentioned above or about 80 c. c. up to the neck, should be provided, as a double quantity of milk may then be taken. This will increase the quantity of fat, and proportionately diminish the error of reading. When this is done the divisions of the scale are equivalent to .1 per cent. of the fat instead of .2 per cent., as is the case where only 18 grams of milk are used. Such bottles are also convenient in making composite tests as described on page 239.

The divisions of the scale on the necks of the bottles should be uniform, and the lines should run straight across the neck, and not obliquely, as is sometimes the case.

When new, the lines and numbers of the scale are usually blackened so that they are easily distinguished, but after the bottles have been cleaned a number of times the color may be washed away, leaving the lines indistinct. They may be restored by rubbing over the scale with a lead pencil, or if a number of bottles need attention, with a cloth having a little black paint upon it.

The bottles should be numbered in some way. A good method is to have the number stamped upon a copper ring which is slipped over the neck.

I prefer to have the number marked upon the glass with a diamond or etched with fluorhydric acid.

Calibrating the Bottles.—The 10 per cent. of the fat represented upon the necks of the bottles correspond to a volume 2 c. c. It is divided into 50 equal parts, 5 of which are equal to 1 per cent. The accuracy of the scale may be approximately determined by filling the bottle to the 0 mark with water and after wiping out the neck of the bottle with

a piece of filter paper, measuring into the bottle 2 c. c. of water, with a delicate pipette, which should fill the bottle to the 10 per cent. mark. If a chemical balance is available the calibration may be accurately made by weighing the bottle when it is filled to the 0 mark and again after it is filled to the 10 per cent. mark with water, care being taken to wipe all of the moisture from the neck of the bottle before each weighing. The difference in weight should be 2 grams. The calibration may be more rapidly done by introducing 2 c. c. of mercury into the bottle and, after fitting a small cork into the mouth of the bottle, inverting it so that the mercury will flow into the neck; the length of the column may then be measured with a pair of dividers; this length should correspond with the length of the scale from 0 to the 10 per cent. mark. The same mercury may be easily transferred from one bottle to another by connecting the necks of the bottles with a short piece of rubber tubing and inverting them. In this way a large number of bottles may be calibrated with the same volume of mercury. In doing this care must be taken that no drops of mercury are left adhering to the sides of the bottles. As the specific gravity of mercury is 13.59, two cubic centimeters will weigh 27.18 grams. Where facilities for weighing are at hand this quantity may be weighed out, and 2 c. c. obtained with great accuracy, as slight errors in weighing do not materially affect the volume. In comparing bottles in this manner the bottles should be clean and dry. Bottles which vary more than 0.2 per cent. in the whole length of the scale from 0 to 10 per cent. should not be used.

2. *Pipette for Measuring Milk.*—This may be of any form, but that shown in Fig. 59, with a wide opening at the lower end to allow the milk to run out rapidly is to be preferred. It should contain when filled to the mark 17.6 c. c. A pipette of this size will deliver a little less than 17.5 c. c. of milk which, if the milk has the average specific gravity of 1.032, will weigh 18 grams. The pipette should be accurately calibrated. It may be tested by weighing the amount

of mercury necessary to fill it to the mark. The weight of mercury should be 239 grams.

In purchasing apparatus for this test, be sure to obtain pipettes containing 17.6 c. c. This precaution is necessary as pipettes of several different sizes have been furnished with this test. This has usually been done on the plea that the larger pipettes give readings which will agree with the butter yield from the churn. This, however, is not the case, and cannot be accomplished by any test, as the yield of butter depends so largely upon the skill of the dairyman. The test is designed to show the amount of pure butter fat in the milk, and not the butter which will be made from it.

3. *A Measure for Acid.*—A graduate or cylinder of glass, Fig. 60, with a lip to pour from and a single mark at 17.5 c. c., is the best form for general use.

It is not essential that this measure be accurately calibrated, as slight variations in the amount of acid used will not affect the results by the test.

The automatic pipettes, for delivering the proper amount of acid directly from the carboy to the test bottles, devised by Prof. Farrington* and Prof. Patrick† may be used with advantage in laboratories or factories where large numbers of tests are made each day. These devices, however, should only be placed in the hands of persons accustomed to handling delicate apparatus, as the glass parts are expensive and liable to breakage if carelessly handled.

4. *Centrifugal Machine.*—So far as I have seen, all of the machines made for this test by the leading dairy supply firms, are suitable for the purpose. A machine should be capable of making from 700 to 1200 revolutions per minute, according to the diameter of the wheel which carries the bottles. A small wheel should make more revolutions than a large one. A wheel less than 12 inches in diameter is not practical and it need not exceed 20 inches. In machines where the motion is transmitted by belt or by friction the adjustment should be kept tight enough to avoid slipping, as otherwise the motion may be much less than is intended

*Bulletin 16, Ill. Agr. Expt. Station, 1891.

†Bulletin 19, Iowa Agr. Expt. Station, 1892.

and result in an imperfect separation of the fat. Machines which carry an even number of bottles are greatly to be preferred, as in such the bottles are placed directly oppo-posite each other, thus making it easy to preserve the equilibrium of the apparatus when a few tests are made.

Recently a number of steam turbine machines have been introduced which have many advantages for factories where high pressure steam is available, as they maintain an even speed, prevent the cooling of the bottles and supply hot distilled water for filling.

5. *Commercial sulfuric acid* having a specific gravity of 1.82–1.83. The stronger acid is to be preferred. It is very important that the acid used have approximately the right strength. If it has a specific gravity much below 1.82, the casein may not be held in solution and being mingled with the fat will give an unsatisfactory test. If the acid is only a trifle too weak the use of a little more may give a good test, but this cannot always be depended upon. If the acid is too strong it will act upon the fat turning it to a dark color, and may char the other solids of the milk which will separate as a black sediment accumulating just beneath the column of fat and prevent a satisfactory reading. If the acid is too strong a good test may be obtained by using less of the acid. The acid should not be diluted.

The acid may be all right and give a satisfactory test when first purchased, and fail to give a good test after a little time. This is occasioned by the acid not being kept in a closed vessel, as under such circumstances the acid rapidly absorbs moisture from the air and soon becomes too weak. The acid should always be kept in a tightly stoppered bottle. The stopper should either be of glass or rubber, as a common cork is soon destroyed by the acid.

Occasionally an acid is obtained which is of the proper strength, but which, owing to some impurities, fails to give a clear separation of the fat. Two or three lots of such acid, which blackened the fat even when used in small quantities and with which it was impossible to obtain satisfactory results have been met with. The cause of the trouble is unknown, and the best remedy is to change such acid for

that from a different lot, as most of the sulfuric acid which has the correct specific gravity will be found to give good results.

When a carboy of acid is purchased the wooden case should not be removed from it, as by so doing the risk of breakage is greatly increased. At least one serious accident has happened in a factory during the past year by carelessly handling a carboy of acid that had been removed from the case.

The acid should always be handled with great care as it is very corrosive, causing serious burns when allowed to to remain upon the skin, and destroying clothes when it comes in contact with them. Whenever acid is spilled upon the hands or clothes it should be washed off immediately, using plenty of water. It is advisable to have a bottle of ammonia water at hand with which to saturate spots where acid has been spattered upon clothes, as this will in most cases restore the color and preserve the fabric.

Boiling water should be provided for filling the bottles after they have been whirled for the first time, and for warming the contents of the bottles if the fat becomes too cold for reading. Distilled or rain water is to be preferred for filling the bottles, as hard water often causes bubbles to form upon the surface of the fat and render the reading difficult.

MAKING THE TEST.

Sampling the Milk.—Every precaution should be taken to have the sample represent as nearly as possible the whole lot of milk from which it is taken. Milk fresh from the cow, while still warm and before the cream has separated in a layer, may be thoroughly mixed by pouring three or four times from one vessel to another. Samples taken at once from milk mixed in this way are the most satisfactory of any. Milk that has stood until a layer of cream has formed should be poured more times, until the cream is thoroughly broken up and the whole appears homogeneous. No clots of cream should appear upon the surface when the milk is left quiet for a moment. With proper care any

milk that has not coagulated or that has not been exposed to the air until the surface of the cream has become dried, may be mixed so that a representative sample can be taken. Milk should not be poured more times than is necessary, as extended mixing in this way is liable to churn the cream, forming little granules of butter that quickly rise to the surface. When this occurs it is impossible to obtain a fair sample and it is useless to make an examination. Milk is sometimes churned by being transported long distances in vessels that are not full.

It is impracticable to sample a large amount of sour milk, but a small sample of a pint to a quart may be thoroughly mixed by adding five per cent. by volume, of strong ammonia water which will dissolve the curde and permit a uniform mixture being made. When ammonia is added the final results should be increased by five per cent. Sour milk may also be treated with concentrated lye in the manner described for making composite tests, page 239. Samples from sour milk are, however, never as satisfactory as those taken when the milk is in a proper condition.

SAMPLING MILK IN FACTORIES.

One of the chief obstacles to the introduction of the system of paying for milk according to its value, as shown by the amount of fat which it contains, has been the fear that representative samples of each patron's milk could not be obtained at the factory without much trouble and expense. Experience has shown, however, that this fear is ungrounded and that any person competent to weigh the milk and keep the necessary records, can take fair samples of each lot of milk received. This may be accomplished in several ways, one of the following being recommended: By stirring the milk with a long handled dipper after it has been poured into the weigh can and dipping out a small portion from which the test sample is measured, or by inserting a small tube in the bottom of the conductor pipe, through which a small portion of the milk continually escapes and is caught in a vessel placed to receive it. The same end may be attained

by laying a small tube in the bottom of the conductor pipe, having it project a foot or more beyond the end, and placing a small vessel to receive the portion of milk which runs through the tube. Samples may also be taken with the "milk thief," which is a tube, with the valve at the lower end, that is lowered into the milk in the weigh can, taking a column of milk from the top to the bottom of the can. A representative sample may be taken by any of these methods, but my preference is for one of the first three named.

When milk is delivered at the factory only every other day the cream often becomes so firm that clots of it quickly rise to the surface after the milk is poured into the weigh can. Such milk is difficult to sample, the result of the test usually being too low. I believe the most satisfactory sample will be obtained in such cases by mixing the samples in the weigh can with a dipper, taking out a small portion which may be poured from one vessel to another until the clots disappear, after which the test samples should be measured. The best practice is to have the test bottles arranged in a case convenient to the weigh can and to measure the test samples directly into the bottles as the milk is received.

Measuring the Milk.—When the milk has been sufficiently mixed, the milk pipette is filled by placing its lower end in the milk can and sucking at the upper end until the milk rises above the mark on the stem; then remove the pipette from the mouth and quickly close the tube at the upper end by firmly pressing the end of the index finger upon it to prevent access of air. So long as this is done the milk cannot flow from the pipette. Holding the pipette in a perpendicular position, with the mark on a level with the eye, carefully relieve the pressure on the finger so as to admit air slowly to the space above the milk. In order to more easily control the access of air both the finger and end of the pipette should be dry. When the upper surface of the milk coincides with the mark upon the stem, the pressure should be removed to stop the flow of milk. Next, place the point of the pipette in the mouth of one of the test bottles, held

in a slightly inclined position so that the milk will flow down the side of the tube leaving a space for the air to escape without clogging the neck, and remove the finger, allowing the milk to flow into the bottle. After waiting a short time for the pipette to drain, blow into the upper end to expel the milk held by capillary attraction in the point. If the pipette is not dry when used it should be filled with the milk to be tested, and this thrown away before taking the test sample. If several samples of the same milk are taken for comparison, the milk should be poured once from one vessel to another after each sample is measured. Neglect of this precaution may make a perceptible difference in the results, through the separation of cream, especially when the milk examined is rich.

Persons who have had no experience in the use of the pipette will do well to practice a short time by measuring water into a test bottle before at tempting to make an analysis.

Adding the acid.—After the milk has been measured into the test bottle the test may be proceeded with immediately, or the bottles may be left for a day or two without materially changing the results; samples that have remained in the test bottles two or three weeks and which had commenced to mould before the acid was added, have given the same amount of fat as samples tested immediately after being measured. It is advisable, however, that the test be proceeded with immediately after the samples are measured, if possible. If the milk has become coagulated, the curd should be broken up by shaking the test bottle before the acid is added.

The volume of commercial sulfuric acid required for a test is approximately the same as that of the milk, or 17.5 c. c. for the ordinary test. If too little acid is added, the casein is not all held in solution throughout the test, and an imperfect separation of the fat results. If too much acid is used, the fat itself is attacked. The acid need not be measured with great accuracy, as small variations will not affect the result.

When all of the samples of milk to be tested are measured

ready for the test, the acid measure is filled to the 17.5 c. c. mark with sulfuric acid, and from this it is carefully poured into the test bottle, containing the milk, that is held in a slightly inclined position for reasons given in directions for measuring the milk. The acid being much heavier than milk sinks directly to the bottom of the test bottle without mixing with the milk that floats upon it. The acid and milk should be thoroughly mixed together by gently shaking with a rotary motion. At first there is a precipitation of curd from the milk, but this rapidly dissolves. There is a large amount of heat evolved by the chemical action, and the solution, at first nearly colorless, soon changes to a very dark brown, owing to the charring of the milk sugar and perhaps some other constituents of the milk.

Whirling the bottles.—The test bottles containing the mixture of milk and acid should be placed in the machine and whirled directly after the acid is added. An even number of bottles should be whirled at the same time, and they should be placed in the wheel in pairs opposite to each other, so that the equilibrium of the apparatus will not be disturbed. When all the test bottles are put in the apparatus, the cover is placed upon the jacket, and the machine turned at the proper speed for about five minutes. The test should never be made without the cover being placed upon the jacket as this not only prevents the cooling of the bottles when they are whirled, but in case of the breakage of bottles may protect the face and eyes of the operator from injury by piece of glass or hot acid. The machine should be frequently examined to make certain that there is no slipping of belts or frictional bearings which may cause too slow motion and result in an imperfect separation of the fat. Managed in this way no extra heat is required, as that caused by the chemical action is sufficient to keep the fat liquid. If the bottles have stood, after the acid is added, until the contents are cooled below 100° F., they should be warmed to about 200° F. before whirling, by placing them in hot water.

Filling the bottles with hot water.—As soon as the bottles have been sufficiently whirled, they should be filled with hot

water to about the seven per cent. mark. If practical, distilled or rain water should be used for the purpose. The bottles are most conveniently filled by placing a vessel containing boiling water above the machine, and by means of a syphon made from a small rubber tube with a glass tip, the water is run directly into the bottles without removing them from the wheel. The flow of water can be perfectly controlled by a pinch-cock upon the rubber tube. If only a few tests are to be made, the bottles may be easily filled with a pipette, or by pouring from a graduate. The cover should then be replaced and the machine turned for about one minute, after which the fat should be measured.

If, when managed in this way, clots of curd or other matter are mingled with the fat, making the reading uncertain, the difficulty can usually be avoided by adding the hot water in two portions, filling the bottle at first only to the neck and after whirling for about one minute, adding sufficient hot water to bring the fat into the graduated neck, after which the bottle should be whirled and the fat measured.

Measuring the fat.—The fat when measured should be warm enough to flow readily, so that the line between the acid liquid and the column of fat will quickly assume a horizontal position when the bottle is removed from the machine. Any temperature between 110° F. and 150° F. will answer, but the higher temperature is to be preferred. The slight difference in the volume of fat due to this difference in temperature is not sufficient to materially affect results.

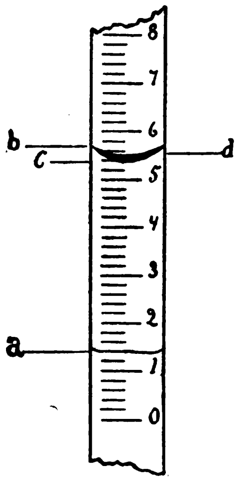


Fig 61.

To measure the fat, take a bottle from its socket, and holding it in a perpendicular position with the scale on a level with the eye, observe the divisions which mark the highest and the lowest limits of the fat. The difference between these give the per cent. of fat directly. The reading can easily be taken to half divisions or to one-tenth per cent.

The line of division between the fat

and the liquid beneath is nearly a straight line, and no doubt need a rise concerning the reading at this point, but the upper surface of the fat being concave, errors often occur by reading from the wrong place. The reading should be taken at the line where the upper surface of the fat meets the side of the tube and not from surface of fat in the center of the tube, nor from the bottom of the dark line caused by the refraction of the curved surface. For instance in Fig. 61 the reading should be taken from a to b and not to c or d.

The reading may be made with less liability of error by measuring the length of the column of fat with a pair of dividers, one point of which is placed at the bottom and the other at the upper limit of the fat. The dividers are then removed and one point being placed at the O mark of the scale on the bottle used, the other will be at the per cent. of fat in the milk examined.

Sometimes bubbles of air collect at the upper surface of the column of fat and prevent a close reading; in such cases a few drops of strong alcohol (over 90 per cent.) put into the tube on top of the column of fat, will cause the bubbles to disappear and give a sharp line between the fat and alcohol for the reading. Whenever alcohol is used for this purpose the reading should be taken directly after the alcohol is added, as after it has stood for a time, the alcohol partially unites with the fat and increases its volume.

Whenever the fat is not quite clear, more satisfactory results may be obtained by allowing the bottles to stand until the fat has crystalized and then warm them by placing the bottles in hot water, before taking the reading.

If the column of fat is less than about one division, as will often happen with skim-milk, buttermilk or whey, it may assume a globular form instead of a uniform layer across the tube; when this occurs the fat can usually be estimated with sufficient accuracy by simple inspection, but in such cases it is better to take a double portion of milk in a large bottle.

TESTING SKIM-MILK, BUTTERMILK AND WHEY.

With all products like the above which usually contain less than one per cent. of fat more accurate results are obtained by the use of a special test bottle which contains twice as much as the ordinary bottle. In such a bottle twice the usual amount of milk and acid can be taken, and the column of fat being doubled in length, may be read read with greater accuracy. In this case the reading of the scale should be divided by two for the true per cent. of the fat. Less acid is required for whey than for milk.

If only traces of fat appear in the neck of the bottle, the fat in the milk examined may be nearly 0.1 per cent. and this reading will be more nearly correct than estimates of from 01. to .05 per cent. which often appear in the agricultural papers. The reason for this is that minute quantities of fat are either dissolved or not separated by the method. The amount of fat lost in this way is about the same for all milks; it is compensated for, when sufficient fat is present to form a complete layer across the neck of the bottle, by reading to the point where the fat meets the glass instead of at the concave surface.

CREAM.

The chief difficulty in testing cream lies in the sampling. Cream that is sour, or that has been exposed to air until the surface has dried, cannot be accurately sampled. The same is true of centrifugal cream that is badly frothed. Sweet cream, from Cooley cans, that is not too thick to flow readily from the pipette may be tested with satisfactory results. The process, however, must be modified slightly from that used with miik, as the amount of fat in cream is so large that it cannot be measured in the ordinary test bottle, if the usual quantity is taken for the test; besides a much greater error results from the cream which adheres to the pipette than with milk. Both of these difficulties may be overcome by taking two or three test bottles and dividing the test sample between them into as nearly

equal portions as can be judged by the eye. The pipette is then filled with water and this is run into the tubes in the same way as the cream. If three bottles are taken the pipette is filled with water a second time and emptied into the bottles as before. This serves to rinse the cream from the pipette, and at the sametime to dilute it to a point where it can be tested in the same way as milk. The bottles are then treated in the usual manner, and the reading of the tubes added together for the per cent. of fat in the cream. The necessity of dividing the sample of cream as directed above may be avoided by the use of the special test bottle shown in Fig. 58. Cream may also be tested in the ordinary bottle by diluting it with three times its volume of water and proceeding in exactly the same manner as with milk, the reading being multiplied by three.

Owing to the low specfiic gravity of cream, the test sample, if of the same volume, will weigh less than that of milk, and consequently the per cent. of fat as shown by the scale will be less than is found by gravimetric analysis, in proportion as the weight is less than 18 grms. Where a delicate balance is available, this error may be entirely avoided by weighing the cream used in the test, and calculating the per cent. of fat by multiplying the scale reading by 18, and dividing the product by the weight in grams of cream taken.

If 17.6 c. c. of cream is taken and the portion adhering to the pipette is rinsed into the test bottle, a close approximation of the true result may be obtained without weighing by correcting the scale reading as follows: For a scale reading of 20 per cent., add 0.25 per cent.; for a scale reading of 15 per cent., add 0.1 per cent. Readings between these may be corrected in proportion. Below 10 per cent. no correction is necessary.

Cream may be tested in the ordinary bottles in the manner proposed by Mr. Winton in bulletin 108, of the Conneticut Experimental Station, by using a pipette having a capacity of 6 04 c. c. which will deliver about 6 grams of average cream or one third of the weight of the usual sample. When this pipette is used, about 12 c. c. of water should be

added to the cream in the bottle before adding the acid. The usual amount of acid should be taken and the test completed in exactly the same way as with milk. The reading should be multiplied by three to obtain the per cent. of fat in the cream. No correction for the specific gravity is necessary when this pipette is used. With either of these modifications the test may, with advantage, replace the oil test churn in gathering cream factories.

CONDENSED MILK.

The estimation of fat in condensed milk is accomplished in exactly the same way as with cream. As a rule condensed milks are so thick that it is impractical to measure the test sample directly with a pipette. This difficulty may be overcome by carefully diluting the milk with a known volume of water, making the analysis of this and correcting the result for the quantity of water added. The best method is to weigh the samples into a test bottle, taking about 8 grams, and after adding about 10 c. c. of water completing the test in the same manner as wth milk, the per cent. of fat being obtained by multiplying the reading by 18 and dividing the product by the weight, in grams of the substance taken. The results are satisfactory.

CHEESE.

The examination of cheese is not as satisfactory as that of other dairy products. The chief reason for this is the unequal distribution of moisture and fat in the cheese, making it very difficult to obtain representative samples. On account of this, tests made from different parts of the same cheese, especially if it be very rich, often vary as much as two or three per cent. in the amount of fat found. To avoid this, as much as possible, samples should be taken in a uniform manner. The following is the provisional method adopted by the Association of Official Agricultural Chemists at its last meeting.*

"Where the cheese can be cut, a narrow wedge reaching from the edge to the center of the cheese will more nearly

*Bulletin 35, U. S. Dept. of Agriculture, Division of Chemistry, 1892.

represent the average composition of the cheese than any other sample. This may be chopped quite fine, with care care to avoid evaporation of water, and the portion for analysis taken from the mixed mass. When the sample is taken with a cheese tryer, a plug taken perpendicular to the surface, one-third of the distance from the edge to the center of the cheese should more nearly represent the average composition than any other. The plug should either reach entirely through or only half through the cheese. For inspection purposes the rind may be rejected but for investigations, where the absolute quantity of fat in the cheese is required the rind should be included in the sample. It is well when admissible, to take two or three plugs on different sides of the cheese, and, after splitting them lengthwise with a sharp knife, take portions of each for the test.

For the estimation of fat in cheese about 5 grams should be carefully weighed and transferred as completely as possible to a test bottle. From 12 to 15 c. c. of hot water are then added and the bottle shaken at intervals, keeping it warm, until the cheese has become softened, and converted into a creamy emulsion. This may be greatly facilitated by the addition of a few drops of strong ammonia to the contents of the bottle. After the contents of the bottles have become cold the usual amount of acid should be added and the bottles shaken until the lumps of cheese have entirely dissolved. The bottles are then placed in the machine and whirled, the test being completed in the same manner as with milk. To obtain the per cent. of fat the reading should be multiplied by 18 and divided by the weight, in grams, of cheese taken.

THE COMPOSITE TEST.

Although it is quite generally admitted that the quality as well as quantity of milk delivered, should be considered in making dividends in factories where milk is pooled. Many who recognize the justice of the relative value plan hesitate to adopt it on account of the labor and expense involved in making daily tests from each patron's milk. The

The best plan yet proposed for reducing the expense of the necessary tests is that first described by Prof. Patrick.* This plan consists in putting a sample from each lot of milk which a patron delivers, successively, into a fruit jar or other suitable vessel which can be tightly closed and, after a number of days, ascertain the average per cent. of fat in all of the milk delivered by the patron, for the time considered by a single test of the composite sample. In order that the composite sample may truly represent the average of all the milk delivered by a patron, the daily sample should of course be proportioned to the amount of milk which he delivers each day. It has been found, however, in practice that scarcely any error is introduced when the daily samples are of uniform size. Prof. Patrick recommended that a small quantity of corrosive sublimate be placed in the jar in which the composite sample is kept, in order to prevent the souring of the milk and keep it in a condition which admits of a representative sample being taken for analysis. On account of the very poisonous nature of corrosive sublimate, its use is to be discouraged if the same end can be attained by other means that are not dangerous.

Boracic acid, borax and salicylic acid have each been used to advantage for preserving composite samples. None of these substances is entirely satisfactory as samples treated with them often become coagulated, especially in hot weather before the test is complete.

PRESERVING COMPOSITE SAMPLES WITH POTASSIUM BICHROMATE.

The discovery by Mr. J. A. Alen,† a Swedish chemist, that potassium bichromate will preserve milk from coagulation and in excellent condition for testing for a long time, offers the most satisfactory solution to this problem yet proposed. This salt, although poisonous, is not so violent a poison as corrosive sublimate and may be used with comparatively little danger. On account of its bright orange

*Bulletin No. 9, of the Iowa Experiment Station.

†Biedermann's Centralblatt für Agrikulturchemie, 1892, p. 549.

color it is not likely to be mistaken for any other substance used in the dairy and the tint which it imparts to milk, without the addition of any other coloring matter, is so marked that there is no danger of milk that has been treated with it being used for domestic purposes.

The use of potassium bichromate for the preservation of composite samples of milk has been thoroughly tested with most satisfactory results by students of the Wisconsin Dairy School during the past winter. Samples of milk have been kept in this way, in a warm room, for more than a month without being coagulated, and determinations of fat in these samples at frequent intervals, have shown no change in the amount of fat found. In all 114 composite tests were made by this method. Each of these was made up of either four or six samples of milk, ranging from partly skimmed milk containing little fat to very rich milk, containing more than 6 per cent. of fat. The samples were kept in a warm room from eight to ten days after the first portion was added and were without exception in good condition when the final test was made. All determinations of fat, both in the single and composite samples, were made in duplicate, the bottles containing the tests being shown to to the instructor in charge and a written report of the test given to him each day. The final results are given below:

Average per cent. of fat in all single samples, 3.676.

Average per cent. of fat in all composite samples, 3.654.

Of the 114 trials there were only four in which the difference between the composite test and the average of the single tests exceeded two-tenths per cent., and in all of these the milk was partially churned by too much mixing, making it impossible to obtain a representative sample of the composite. Of the remaining 110 trials only ten gave differences larger than one-tenth per cent. fat and in forty trials the composite test agreed exactly with the average per cent. of fat in the single tests. These results are far better than we have obtained by any other method and I believe warrant its adoption in factories.

In making tests on this plan a pint or quart fruit jar

should be provided for each patron. Into each of these jars should be placed from ¼ to ½ gram of powdered potassium bichromate. This need not be weighed as the amount can vary considerable without affecting results. The amount specified is about one-half as much as would lie upon a cent, or as much as can be taken upon a pen knife blade one inch long. This will be sufficient to preserve from a pint to a quart a week. A little experience will teach one how much to use; enough should be used to tint the whole sample a light straw color and it should be perfectly liquid when the final test is made; if this is not the case, more should be used.

Each jar is labeled or numbered to designate the patron to whom it belongs and into it is placed a measured sample of his milk each day until the test is made.

A small tin cylinder holding from one to two ounces of milk when filled to the brim makes a convenient measure for this purpose. Whenever a fresh sample of milk is placed in the jar it should be mixed with the milk previously added by giving the jar a rotary motion; unless this is done the cream which separates may adhere tenaciously to the sides of the jar and prevent the taking of an accurate sample when the test is made. The jars should be tightly closed after each sample of milk has been added, and should be kept in a cool place during the week.

If kept too warm the cream will become so hard that it cannot be mixed with the sample without danger of churning, which will always lead to low results. The test of the composite sample is made in exactly the same way as with fresh milk.

This method of preserving composite samples has been patented by Mr. Alen in Sweden, but so far as I know no restrictions are placed upon its use in this country.

OTHER METHODS OF MAKING COMPOSITE TESTS.

Prof. Farrington,* Chemist of the Illinois Agricultural Experiment Station, has recommended that the daily

*Bulletin No. 16, Ill. Agr. Expt. Station 1891, p. 510.

samples be placed in jars as described above and that nothing be added to them to prevent souring. When ready for the test, about one-half a teaspoonful of finely powdered concentrated lye is added, in small portions at a time to each jar, which should be shaken occasionally, or poured from one jar to another, until the curdled milk has all dissolved and the cream become mingled with the milk. Solution may be hastened by warming the contents of the jar to a little over 100° F. The temperature should not exceed 140° F., and the covers should be kept upon the jars when warm, to prevent evaporation. When the milk in the jars has become thin and homogeneous a sample may be measured and tested for fat in exactly the same way as with new milk, the result being the average per cent. of fat in the milk delivered, for the period covered by the samples. Tests of this kind should not extend over a longer period than one week.

A very satisfactory composite test may be made, without the trouble of dissolving the curd, by using a test bottle of twice the usual size, such as is recommended for skim-milk, for each patron, and measuring into this with a 5 c. c. pipette a sample of his milk each day for seven days. The bottle will then contain double the usual test sample, and by adding double the usual amount of acid the test may be completed as with fresh milk. It is well to shake up the contents of the bottle before adding the acid. The reading should be divided by two for the per cent. of fat. A composite test for three days can be obtained in this way in the ordinary test bottles by using a pipette containing 5.9 c. c., making the test in just the same way as with fresh milk.

The objections to this method are that more care is required in taking the daily samples, and in case of an accident in making the test, the record for the time covered by the composite sample is lost. The result is accurate and the time required less than by any other method.

THE "RELATIVE VALUE PLAN" OF MAKING DIVIDENDS IN FACTORIES.

This system assumes that the relative value of all milks that are pooled together for either butter or cheese, are in direct proportion to the amount of fat which the milks contain. The method is applied in co-operative factories by dividing the net proceeds between the different patrons, in proportion to the total amount of fat, which the milk delivered by each patron contains, for the time covered by the dividend. In factories where milk is purchased, a price is agreed upon for milk of a certain standard, say one dollar per 100 lbs. for milk containing 4 per cent. of fat, the price paid being greater or less than this in proportion as the per cent. of the fat is above or below 4 per cent. The following example, showing the weight and quality of milk delivered by different patrons, with the weight of butter or cheese made and money received for it, will illustrate:

Name of Patron.	Lbs of Milk.	Per cent of fat.	Fat, lbs.
A	2,000	3.25	65.
B	750	4.00	30.
C	1,275	5.2	66.3
D	1,500	3.6	54.
Total fat lbs			215.3

The total fat in each patron's milk is found by multiplying the number of pounds of milk by one hundredth of the per cent of the per cent. of fat, thus:

2,000 × .0325=65, the pounds of fat in A's milk.

750 × .04=30, the pounds of fat in B's milk, etc.

From the pooled milk the yield of butter was 240 pounds which was sold for twenty-five cents per pound, making $60.00 in all. The cost of making, including freight, etc.,

was four cents per pound, or $9.60, which deducted from the gross sales leave $50.40 to be divided between A, B, C and D in proportion to the fat which each had delivered at the factory. Dividing the net sum of $50.40 by 215.3, the total pounds of fat received, gives $.23409 per pound for the fat. Multipyling the pounds of fat in each patron's milk by the price per pound gives the amount which each receives:

Name of Patron.		Amount which each receives.
A	65 × .23409 =	$15.216
B	30 × .23409 =	7.023
C	66.3 × .23409 =	15.520
D	54 × .23409 =	12.641
Total		$50.400

If the above milk was made into cheese, the yield being 570 lbs., which sold for $.10½ per lb., the cost of making, selling, freight, etc., being 1½ cents per lb. there would be $51.30 to divide. This for the 215.3 lbs. fat is $.23827 per lb., giving each patron as below:

Patron.		Am't which each receives.
A	65 × .23827 =	$15.488
B	30 × .23857 =	7.148
C	66.3 × .23827 =	15.797
D	54 × .23827 =	12.867
Total		$51.300

If this milk had been purchased at the rate of $1.00 per 100 lbs. for four per cent. milk, this would have been at the rate of $.25 per lb. for fat and each patron would have received:

16—Ex.

Patron.		Amt. which each receives.
A	65 × .25 =	$16.25
B	30 × .25 =	7.50
C	66.3 × .25 =	16.575
D	54 × .25 =	13.50
		$53.825

When the composite test is used the time represented in the above example is one week, or whatever time is included in the test, the pounds of milk being the total for the period and the per cent. of fat the average as shown by the test. If more than one period is covered the fat is calculated for each separately and all added together for the total fat, instead of calculating it from the total pounds of milk and average of the different per cents. of fat. If daily tests are made the fat in each patron's milk should be calculated each day, the sum for the whole period covered by the sale being the total fat upon which the dividend is made.

As this report is going through the press, the following letter was received from Prof. E. H. Farrington, who has charge of the chemical work connected with the Dairy Tests at the World's Columbian Exposition, gives additional precautions in regard to testing milk by the method described in the preceding pages, and will be read with interest and profit:

CHEMICAL LABORATORY OF THE WORLD'S COLUMBIAN EXPOSITION DAIRY TEST.
JACKSON PARK, CHICAGO, ILL., AUGUST 1, '93.

DR. S. M. BABCOCK,
Madison, Wis.

My Dear Sir.—In reply to your request I venture to make a few suggesgestions in regard to some of the manipulations in the Babcock Milk Test.

These observations are the results a great many experiments made with the milk of each of the seventy-five cows now in the dairy test at the World's Columbian Exposition.

Since May 1st, '93, we have made at least one hundred and fifty tests of milk every day. During this time samples have been tested of a great variety of milks. There have been great variations in the composition of these milks and in the characteristics and health of the cows. We have

been able to test successfully, any milk yet received, and by proper manipulation, to get a very clear separation of the fat.

A bad separation of fat is not always caused by the strength of the sulfuric acid.

Our work has demonstrated that by slight changes in the manipulation, at least three kinds of tests can be made of one sample of milk with the same acid.

First—A test giving a very clear separation of fat.

Second—A separation of fat which contains more or less of a black, flocculent substance, especially at the bottom of the fat column, and

Third—A test very much like the second except that a white instead of a black substance interferes with a clear measurement of the fat.

The black substance that appears is probably charred fat and indicates too strong an action of the acid on the milk. The white adulteration of the fat shows either too weak a reaction or an incomplete separation by the centrifuge. Each of these two defects can of course be produced by acid either very much too strong or too weak. They can also be caused by different manipulation when acid having the correct strength is used.

If the acid is so poured into the milk in the test bottle, that it passes through the milk, instead of running down the inside walls of the test bottle, a portion of the milk is thus acted on by the strong acid before it becomes diluted with the water in the milk. This makes a more intense action of the acid on a small part of the milk, and the fat it contains is somewhat decomposed and blackened. This black substance is then separated with the fat by the usual process of finishing the test and makes the measurement of the fat uncertain.

Another cause of the "black stuff" in the fat is too warm milk.

Sulfuric acid sp. gr, 1.82 may work all right for testing milk when both acid and milk are at a temperature of 60° Fahr, but if the weather changes or the testing is made in a warm room where the temperature is up to 80° or 90° F. a great deal of black stuff will be found in the fat.

The action of the acid on the milk will be more or less intense according to the temperature of the liquids.

Persons who have tested milk throughout the year at creameries or other places, may have noticed that in winter the fat is often light colored or whitish, while in summer it is a deep yellow. This is caused by the difference in the temperature of the milk and acid as well as the strength of the acid.

Cooling the milk before adding acid to the test bottle, will often prevent the formation of the black substance which appears in the column of fat.

The white "curdy" substance that sometimes separates with the fat, can be destroyed, either by adding the hot water necessary to bring the fat up into the neck of the test bottle, in two portions and whirling the test bottles in the centrifuge after each addition of water, or by warming the

milk in the test bottles so that it will be about 80° Fahr. when the acid is added.

It is my opinion that any person who has trouble from either the black or white substance separating with the fat, can remedy the difficulty by some changes in the manipulation, provided the acid is anywhere between 1.82 and 1.83 sp. gr. No exact experiments have been made yet to determine the relation between the temperature of the milk and sp. gr. of the acid, but I will venture to guarantee an entirely satisfactory working of the Babcock milk test, if in addition to the elaborate detail you have already worked out, the following precautions are observed:

First.—An acid having sp. gr. 1.82 should be used with milk at 60° to 70° Fahr. If the acid is stronger cool the milk to a lower temperature. Somewhat weaker acid can probably be made to work all right by warming the milk.

Second.—When measuring the acid into the test bottle, hold the bottle at an angle that will cause the acid to follow the inside walls to the bottom of the bottle and not drop through the milk in the center of the bottle. If properly poured into the test bottle there will be a distinct layer of milk and acid with no black color between them.

Third.—Thoroughly mix the milk and acid as soon as measured into the test bottle. A better separation of fat is obtained by mixing at once rather than by allowing the two liquids to stand unmixed, until enough tests have been measured out to fill the centrifuge.

Fourth.—After five minutes whirling of the test bottle in the centrifuge, add hot water until the test bottle is filled up to the neck only; run the centrifuge one minute, then fill the neck of the test bottle with hot water and run the centrifuge another minute. Adding the necessary hot water in two portions is often a great help in getting a clear separation of fat. When the test bottles are finally taken from the centrifuge, they are put into hot water 140° to 160° F. and the per cent. of fat read at that temperature.

Fifth—Too low results will be obtained if the centrifuge does not have sufficient speed. The machines have to be watched, as constant use wears some of them so that the speed designed by the manufacturer is not obtained.

Very Respectfully Yours,

E. H. FARRINGTON,

DETECTION OF ADULTERATIONS IN MILK.

S. M. BABCOCK.

The most usual adulterations of milk are the addition of water and the abstraction of fat. Those factorymen and dealers who pay for milk according to its quality, as recommended in this bulletin, need have no fears of either of these adulturations, as the system makes it the interest of every man to supply as good milk as possible. As there are, however, many factories that still cling to the old method of paying the same price for all milks independent of their quality, it is thought advisable to describe the methods by which said frauds may be detected.

The detection of these adulterations is rendered possible by the fact that the abstraction of cream reduces the per cent. of fat and slightly increases the per cent. of solids not fat, in the milk which remains. On the other hand, the the addition of water reduces the per cent. of butter fat and solids not fat, in proportion to the amount of water added. For example: If a milk which originally tested 4 per cent. of fat and 9 per cent. of solids not fat be skimmed so that the remaining milk tests only 2 per cent. of fat, the solids not fat in the skimmed milk would be about 9.2 per cent. If on the other hand, enough water has been added to this milk to reduce the fat to 2 per cent. the solids not fat would have been only 4.5 per cent. It is therefore easy to detect either or both of these adulterations, if a sample of the original milk can be obtained; as it is rarely possible in suspected cases to obtain original samples, it is best when practicable, to secure through an authorized agent, who

sees the cows milked, a sample of milk from the same herd with which comparisons may be made. As the amount of fat and solids not fat in the mixed milk from a herd are quite constant in quantity, the fat not usually varying more than .3 per cent. from one day to another, and the solids not fat even less, the sample taken at the farm should correspond, within narrow limits, with previous samples taken from the milk wagon.

In order to maintain a fair quality of milk and insure the public against frauds, many states have established, by law, certain standards which fix the minimun amount of fat and of solids not fat, which commercial milk shall contain and in such states it is illegal to sell milk, as pure, which falls below the standard. It makes no difference whether the milk is poor from watering, from skimming, or from poor cows, the penalty is the same in all cases.

In Wisconsin the legal standard for fat is three per cent., which is as low as any accepted standard in this country or in Europe. In other states the standard ranges from 3 to 3.5 per cent. The general average for all breeds and for all seasons of the year is about 3.6 per cent. of fat, and it is rare for the mixed milk from any herd to fall below 3 per cent. It is possible that the milk from individual cows or from herds which contain only two or three cows, may contain less than the standard demands; but usually herd milk containing less than 3 per cent. of fat with us has been either watered or skimmed.

The legal standard for solids not fat established in England and some of the eastern states is 9 per cent. In Wisconsin there is no legal standard for solids not fat. Milks containing less than 9 per cent. of solids not fat are suspicious, and those containing less than 8.5 are probably watered. In all suspected cases it is advisable, as already suggested, to secure samples from the farm for comparison.

To detect adulterations it is necessary to determine both the fat and the solids not fat. If either of these be below the legal standard, the milk must be considered adulterated even if it has not been tampered with after being milked.

For purposes of inspection the fat may be determined by the method described in this bulletin. The solids not fat may be determined by the usual laboratory methods, or, for practical purposes, they may be calculated with sufficient accuracy from the specific gravity of the milk and the per cent. of fat. The specific gravity should be carefully determined for this purpose.

The following precautions are essential: Milk just after it is drawn is saturated with air which should be allowed to escape before the specific gravity is determined, otherwise the result will be too low. To be on the safe side, milk should stand at least one hour after being milked before the test is made. The temperature of the milk should be brought by warming or cooling to 60° F., and then thoroughly mixed by pouring from one vessel to another with care to avoid, as much as possible, the introduction of small bubbles of air. The specific gravity may then be accurately determined with a picnometer or Westphal balance, but for general purposes a good hydrometer or lactometer is sufficiently accurate, and on account of its convenience is to be preferred.

THE LACTOMETER.

There are several kinds of lactometers in use at the present time, all of which have the same general form, viz.: a narrow stem to which is attached an elongated bulb weighted at the bottom so as to float in an upright position in milk, with the stem partially submerged. (See Fig. 62.) The depth to which the lactometer sinks depends upon the specific gravity of the liquid in which it is placed, a heavy liquid causing the stem to rise higher above the surface than a light liquid. It shows the relative weight of equal volumes of milk tested.

The lactometer most generally used in this country is graduated from 0 to 120 degrees, 0 being the point on the stem, to which the instrument sinks in pure water at 60 °F. and 100 the point to which it sinks in a liquid having a specific gravity of 1.029, this being assumed to be the lowest specific gravity compatible with pure milk. The inter-

mediate readings are intended to show the per cent of milk having a specific gravity of 1.029, which the sample examined contains. This, however, it does not do, for when milk is skimmed it will give a higher reading upon the lactometer than it did before the cream was removed and the addition of cream to milk reduces the reading in the same way as the addition of water. Although an experienced person would rarely if ever be deceived by these readings, owing to the changed appearance of milk that has been skimmed or watered, factorymen and others have often been misled by them. For this reason and also because it is necessary to know the specific gravity of the milk, when the readings are to be used, in connection with the per cent. of fat, for the calculation of total solids, the Quevenne lactometer (see Fig. 62) is to be preferred. The scale of this lactometer expresses in thousandths the the difference between the specific gravity of the liquid tested and water, the specific gravity of water being 1. In other words, the reading of this lactometer is equal to to the specific gravity of the milk in which it is placed. less 1 multiplied by 1,000. To illustrate, milk having a specific gravity of 1.0325 would give with this lactometer a reading of 32.5 and a reading of 33 on this lactometer, corresponds to a specific gravity of 1.033. It is therefore easy to convert lactometer degrees into specific gravity and specific gravity into lactometer degrees. These lactometers are usually graduated from 15 to 40 degrees; if the scale were extended 0, this would be found at that point on the stem to which the instrument sinks in pure water at a temperature of 60° F.

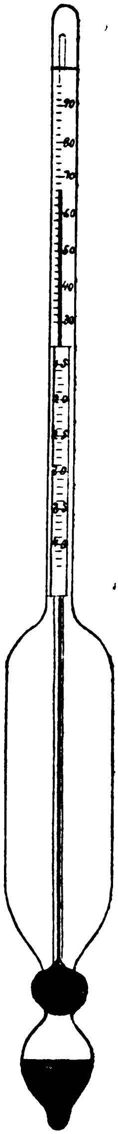


FIG. 62.

The 0 point of both the lactometers mentioned correspond. The scale of the ordinary lactometer may be converted into the Quevenne scale by multiplying by .29. For convenience, a table is given showing the relation between

the two scales. The Quevenne readings are given to the nearest tenth.

Table showing the Quevenne lactometer degrees corresponding to the scale of the ordinary lactometers that are graduated from 0 to 120.

Ordinary Scale.	Quevenne Scale.	Ordinary Scale.	Quevenne Scale.
60	17.4	91	.27 9
61	17.7	92	
62	18.	93	27.3
63	18.3	94	27.3
64	18.6	95	27.6
65	18.8	96	27.8
66	19.1	97	28.1
67	19.4	98	28.4
68	19.7	99	28.7
69	20.	100	29.
70	29.3	101	29.3
71	20.6	102	29.6
72	20.9	103	29.9
73	21 2	104	30.2
74	21.5	105	30.5
75	21.7	106	30.7
76	22.	107	31.
77	22.3	108	31.3
78	22.6	109	31.6
79	22.9	110	31.9
80	23.2	111	32.2
81	23.5	112	32.5
82	23.8	113	32.8
83	24.1	114	33.1
84	24.4	115	33.4
85	24.6	116	33.6
86	24 9	117	33.9
87	25.2	118	34.2
88	35.5	119	34.5
89	25.8	120	34 8
90	26.1		

The sensitiveness of a lactometer depends upon the relation between the volume of the bulb and the diameter of the stem, a large bulb and small stem being most sensitive. A bulb $1\frac{1}{8}$ inch in diameter and 3 inches long with a stem about $\frac{1}{4}$ inch in diameter gives suitable proportions for a dairy lactometer. It is advisable to have the instrument combined with the thermometer, and when this is done it is more convenient to have the the mometer scale placed above the lactometer scale so that both scales can be read without removing the lactometer from the milk.

CORRECTIONS FOR TEMPERATURE.

Although it is always advisable to have the temperature of the milk carefully adjusted to 60° F., when the lactometer leading is taken, corrections for the Quevenne lactometer may be made, for slight deviations (not more than 10°) from the standard temperature, without serious error, by adding to the lactometer reading 0.1 for each degree that the temperature exceeds 60 and subtracting 0.1 for each degree below 60. For example, the lactometer reading is 33.5 and the temperature of the milk is 67° F. The corrected reading for 60° would be 33.5+.7=34.2. Had the temperature been 56° F., the corrected reading would be 33.5—.4=33.1.

Having obtained the per cent. of fat and specific gravity by the above, or any accurate method, the solids not fat may be obtained by reference to the accompanying table which is calculated from the following formula*

$$\text{Solids not fat} = \left\{ \frac{100\,S - Sf}{100 - 1.0753\ Sf} - 1 \right\} \times (100 - f)2.6$$

in which S=Specific gravity of milk at 60° F. and f=per cent. of fat.

The table gives per cents. of solids not fat corresponding to Quevenne lactometer readings (1000 sp. gr.—1000) from 17 to 40 and for each tenth per cent. of fat up to six per cent.

*See 8th Annual Report of Wisconsin Agricultural Expt. Station, p. 293.

Table showing per cent. of solids not fat corresponding to per cent. of fat and Quevenne lactometer reading.

Lactometer reading.	Per Cent. of Fat.																					Lactometer reading.
	.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	
17.......	4.42	4.44	4.46	4.48	4.50	4.52	4.54	4.56	4.58	4.60	4.62	4.64	4.66	4.68	4.70	4.73	4.75	4.77	4.79	4.81	4.83	17
18....	4.68	4.70	4.72	4.74	4.76	4.78	4.80	4.82	4.84	4.86	4.88	4.90	4.92	4.95	4.97	4.99	5.01	5.03	5.05	5.07	5.09	18
19.......	4.94	4.96	4.98	5.00	5.02	5.04	5.06	5.08	5.10	5.12	5.14	5.17	5.19	5.21	5.23	5.25	5.27	5.29	5.31	5.33	5.35	19
20.......	5.20	5.22	5.24	5.26	5.28	5.30	5.32	5.34	5.36	5.38	5.40	5.43	5.45	5.47	5.49	5.51	5.53	5.55	5.57	5.59	5.61	20
21......	5.46	5.48	5.50	5.52	5.54	5.56	5.58	5.60	5.62	5.64	5.66	5.68	5.71	5.73	5.75	5.77	5.79	5.81	5.83	5.85	5.87	21
22.......	5.72	5.74	5.76	5.78	5.80	5.82	5.84	5.86	5.88	5.90	5.93	5.95	5.97	5.99	6.01	6.03	6.05	6.07	6.09	6.11	6.13	22
23.......	5.98	6.00	6.02	6.04	6.06	6.08	6.10	6.12	6.14	6.17	6.19	6.21	6.23	6.25	6.27	6.29	6.31	6.33	6.35	6.37	6.39	23
24.......	6.24	6.26	6.28	6.30	6.32	6.34	6.36	6.38	6.40	6.43	6.45	6.47	6.49	6.51	6.53	6.55	6.57	6.59	6.61	6.63	6.65	24
25.......	6.50	6.52	6.54	6.56	6.58	6.60	6.62	6.64	6.67	6.69	6.71	6.73	6.75	6.77	6.79	6.81	6.83	6.85	6.87	6.90	6.92	25
26.......	6.76	6.78	6.80	6.82	6.84	6.86	6.88	6.91	6.93	6.95	6.97	6.99	7.01	7.03	7.05	7.07	7.09	7.11	7.14	7.16	7.18	26
27.......	7.02	7.04	7.06	7.08	7.10	7.12	7.14	7.17	7.19	7.21	7.23	7.25	7.27	7.29	7.31	7.33	7.35	7.38	7.40	7.42	7.44	27
28.......	7.28	7.30	7.32	7.34	7.36	7.38	7.40	7.43	7.45	7.47	7.49	7.51	7.53	7.55	7.57	7.59	7.61	7.64	7.66	7.68	7.70	28
29.......	7.54	7.56	7.58	7.60	7.62	7.64	7.66	7.69	7.71	7.73	7.75	7.77	7.79	7.81	7.83	7.85	7.88	7.90	7.92	7.94	7.96	29
30.......	7.80	7.82	7.84	7.86	7.88	7.90	7.93	7.95	7.97	7.99	8.01	8.03	8.05	8.07	8.09	8.12	8.14	8.16	8.18	8.20	8.22	30
31.......	8.06	8.08	8.10	8.12	8.14	8.16	8.19	8.21	8.23	8.25	8.27	8.29	8.31	8.33	8.36	8.38	8.40	8.42	8.44	8.46	8.48	31
32.......	8.32	8.34	8.36	8.38	8.40	8.42	8.45	8.47	8.49	8.51	8.53	8.55	8.57	8.59	8.62	8.64	8.66	8.68	8.70	8.72	8.74	32
33.......	8.58	8.60	8.62	8.64	8.66	8.68	8.71	8.73	8.75	8.77	8.79	8.81	8.83	8.85	8.88	8.90	8.92	8.94	8.96	8.98	9.01	33
34.......	8.84	8.86	8.88	8.90	8.92	8.95	8.97	8.99	9.01	9.03	9.05	9.07	9.09	9.12	9.14	9.16	9.18	9.20	9.22	9.24	9.27	34
35.......	9.10	9.12	9.14	9.16	9.18	9.21	9.23	9.25	9.27	9.29	9.31	9.33	9.35	9.38	9.40	9.42	9.44	9.46	9.48	9.51	9.53	35
36.......	9.36	9.38	9.40	9.42	9.44	9.47	9.49	9.51	9.53	9.55	9.57	9.59	9.62	9.64	9.66	9.68	9.70	9.72	9.75	9.77	9.79	36
37.......	9.62	9.64	9.66	9.68	9.70	9.73	9.75	9.77	9.79	9.81	9.83	9.85	9.88	9.90	9.92	9.94	9.96	9.98	10.01	10.03	10.05	37
38.......	9.88	9.90	9.92	9.94	9.97	9.99	10.01	10.03	10.05	10.07	10.09	10.12	10.14	10.16	10.18	10.20	10.22	10.25	10.27	10.29	10.31	38
39.......	10.14	10.16	10.18	10.20	10.23	10.25	10.27	10.29	10.31	10.33	10.35	10.38	10.40	10.42	10.44	10.46	10.48	10.51	10.53	10.55	10.57	39
40.......	10.40	10.42	10.44	10.46	10.49	10.51	10.53	10.55	10.57	10.59	10.61	10.64	10.66	10.68	10.70	10.72	10.75	10.77	10.79	10.81	10.83	40

Table for solids not fat—Continued.

Lactometer reading.	Per Cent of Fat. 2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0
17	4.83	4.85	4.87	4.89	4.91	4.93	4.95	4.97	4.99	5.01	5.03	5.05	5.07	5.09	5.11	5.14	5.16	5.18	5.20	5.22	5.24
18	5.09	5.11	5.13	5.15	5.17	5.19	5.21	5.23	5.25	5.27	5.29	5.31	5.33	5.36	5.38	5.40	5.42	5.44	5.46	5.48	5.50
19	5.35	5.37	5.39	5.41	5.43	5.45	5.47	5.49	5.51	5.54	5.56	5.58	5.60	5.62	5.64	5.66	5.68	5.70	5.72	5.74	5.76
20	5.61	5.63	5.65	5.67	5.69	5.71	5.73	5.76	5.78	5.80	5.82	5.84	5.86	5.88	5.90	5.92	5.94	5.96	5.98	6.00	6.02
21	5.87	5.89	5.91	5.93	5.95	5.98	6.00	6.02	6.04	6.06	6.08	6.10	6.12	6.14	6.16	6.18	6.20	6.22	6.24	6.27	6.29
22	6.13	6.15	6.17	6.19	6.22	6.24	6.26	6.28	6.30	6.32	6.34	6.36	6.38	6.40	6.42	6.44	6.46	6.49	6.51	6.53	6.55
23	6.39	6.41	6.44	6.46	6.48	6.50	6.52	6.54	6.56	6.58	6.60	6.62	6.64	6.66	6.69	6.71	6.73	6.75	6.77	6.79	6.81
24	6.65	6.68	6.70	6.72	6.74	6.76	6.78	6.80	6.82	6.84	6.86	6.88	6.90	6.93	6.95	6.97	6.99	7.01	7.03	7.05	7.07
25	6.92	6.94	6.96	6.98	7.00	7.02	7.04	7.06	7.08	7.10	7.13	7.15	7.17	7.19	7.21	7.23	7.25	7.27	7.29	7.31	7.34
26	7.18	7.20	7.22	7.24	7.26	7.28	7.30	7.32	7.35	7.37	7.39	7.41	7.43	7.45	7.47	7.49	7.51	7.53	7.56	7.58	7.60
27	7.44	7.46	7.48	7.50	7.52	7.54	7.56	7.59	7.61	7.63	7.65	7.67	7.69	7.71	7.73	7.75	7.78	7.80	7.82	7.84	7.86
28	7.70	7.72	7.74	7.76	7.78	7.81	7.83	7.85	7.87	7.89	7.91	7.93	7.95	7.97	8.00	8.02	8.04	8.06	8.08	8.10	8.12
29	7.96	7.98	8.00	8.02	8.05	8.07	8.09	8.11	8.13	8.15	8.17	8.19	8.21	8.24	8.26	8.28	8.30	8.32	8.34	8.36	8.38
30	8.22	8.24	8.26	8.29	8.31	8.33	8.35	8.37	8.39	8.41	8.43	8.46	8.48	8.50	8.52	8.54	8.56	8.58	8.60	8.63	8.65
31	8.48	8.50	8.53	8.55	8.57	8.59	8.61	8.63	8.65	8.67	8.70	8.72	8.74	8.76	8.78	8.80	8.82	8.84	8.87	8.89	8.91
32	8.74	8.77	8.79	8.81	8.83	8.85	8.87	8.89	8.92	8.94	8.96	8.98	9.00	9.02	9.04	9.06	9.09	9.11	9.13	9.15	9.17
33	9.01	9.03	9.05	9.07	9.09	9.11	9.13	9.16	9.18	9.20	9.22	9.24	9.26	9.28	9.30	9.33	9.35	9.37	9.39	9.41	9.43
34	9.27	9.29	9.31	9.33	9.35	9.37	9.39	9.42	9.44	9.46	9.48	9.50	9.52	9.55	9.57	9.59	9.61	9.63	9.65	9.67	9.70
35	9.53	9.55	9.57	9.59	9.61	9.63	9.66	9.68	9.70	9.72	9.74	9.76	9.79	9.81	9.83	9.85	9.87	9.89	9.91	9.94	9.96
36	9.79	9.81	9.83	9.85	9.87	9.90	9.92	9.94	9.96	9.98	10.00	10.03	14.05	10.07	10.09	10.11	10.13	10.16	10.18	10.20	10.22
37	10.05	10.07	10.09	10.11	10.14	10.16	10.18	10.20	10.22	10.24	10.27	10.29	10.31	10.33	10.35	10.37	10.40	10.42	10.44	10.46	10.48
38	10.31	10.33	10.35	10.38	10.40	10.42	10.44	10.46	10.48	10.51	10.53	10.55	10.57	10.59	10.61	10.64	10.66	10.68	10.70	10.72	10.75
39	10.57	10.59	10.62	10.64	10.66	10.68	10.70	10.72	10.75	10.77	10.79	10.81	10.83	10.85	10.88	10.90	10.92	10.94	10.96	10.99	11.01
40	10.83	10.86	10.88	10.90	10.92	10.94	10.96	10.99	11.01	11.03	11.05	11.07	11.09	11.12	11.14	11.16	11.18	11.20	11.23	11.25	11.27

Table for solids not fat—Continued.

Lactometer reading.	PER CENT. OF FAT. 4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	Lactometer reading.
17	5.24	5.26	5.28	5.30	5.32	5.34	5.36	5.38	5.40	5.42	5.44	5.46	5.48	5.51	5.53	5.55	5.57	5.59	5.61	5.63	5.65	**17**
18	5.50	5.52	5.54	5.56	5.58	5.60	5.62	5.64	5.66	5.69	5.71	5.73	5.75	5.77	5.79	5.81	5.83	5.85	5.87	5.89	5.91	**18**
19	5.76	5.78	5.80	5.82	5.84	5.86	5.89	5.91	5.93	5.95	5.97	5.99	6.01	6.03	6.05	6.07	6.09	6.11	6.13	6.16	6.18	**19**
20	6.02	6.04	6.07	6.09	6.11	6.13	6.15	6.17	6.19	6.21	6.23	6.25	6.27	6.29	6.31	6.34	6.36	6.38	6.40	6.42	6.44	**20**
21	6.29	6.31	6.33	6.35	6.37	6.39	6.41	6.43	6.45	6.47	6.49	6.52	6.54	6.56	6.58	6.60	6.62	6.64	6.66	6.68	6.70	**21**
22	6.55	6.57	6.59	6.61	6.63	6.65	6.67	6.69	6.72	6.74	6.76	6.78	6.80	6.82	6.84	6.86	6.88	6.90	6.92	6.95	6.97	**22**
23	6.81	6.83	6.85	6.87	6.89	6.92	6.94	6.96	6.98	7.00	7.02	7.04	7.06	7.08	7.10	7.13	7.15	7.17	7.19	7.21	7.23	**23**
24	7.07	7.09	7.12	7.14	7.16	7.18	7.20	7.22	7.24	7.26	7.28	7.30	7.33	7.35	7.37	7.39	7.41	7.43	7.45	7.47	7.49	**24**
25	7.34	7.36	7.38	7.40	7.42	7.44	7.46	7.48	7.50	7.53	7.55	7.57	7.59	7.61	7.63	7.65	7.67	7.69	7.72	7.74	7.76	**25**
26	7.60	7.62	7.64	7.66	7.68	7.70	7.73	7.75	7.77	7.79	7.81	7.83	7.85	7.87	7.89	7.92	7.94	7.96	7.98	8.00	8.02	**26**
27	7.86	7.88	7.90	7.92	7.94	7.97	7.99	8.01	8.03	8.05	8.07	8.09	8.11	8.14	8.16	8.18	8.20	8.22	8.24	8.26	8.28	**27**
28	8.12	8.14	8.16	8.18	8.21	8.23	8.25	8.27	8.29	8.31	8.33	8.36	8.38	8.40	8.42	8.44	8.46	8.48	8.50	8.53	8.55	**28**
29	8.38	8.41	8.43	8.45	8.47	8.49	8.51	8.53	8.55	8.58	8.60	9.62	8.64	8.66	8.68	8.70	8.73	8.75	8.77	8.79	8.81	**29**
30	8.65	8.67	8.69	8.71	8.73	8.75	8.77	8.80	8.82	8.84	8.86	8.88	8.90	8.92	8.95	8.97	8.99	9.01	9.03	9.05	9.07	**30**
31	8.91	8.93	8.95	8.97	8.99	9.02	9.04	9.06	9.08	9.10	9.12	9.15	9.17	9.19	9.21	9.23	9.25	9.27	9.30	9.32	9.34	**31**
32	9.17	9.19	9.21	9.24	9.26	9.28	9.30	9.32	9.34	9.37	9.39	9.41	9.43	9.45	9.47	9.49	9.52	9.54	9.56	9.58	9.60	**32**
33	9.43	9.46	9.48	9.50	9.52	9.54	9.56	9.58	9.61	9.63	9.65	9.67	9.69	9.71	9.74	9.76	9.78	9.80	9.82	9.84	9.87	**33**
34	9.70	9.72	9.74	9.76	9.78	9.80	9.83	9.85	9.87	9.89	9.91	9.93	9.96	9.98	10.00	10.02	10.04	10.06	10.09	10.11	10.13	**24**
35	9.96	9.98	10.00	10.02	10.04	10.07	10.09	10.11	10.13	10.15	10.17	10.20	10.22	10.24	10.26	10.28	10.31	10.33	10.35	10.37	10.39	**35**
36	10.22	10.24	10.26	10.29	10.31	10.33	10.35	10.37	10.39	10.42	10.44	10.46	10.48	10.50	10.52	10.55	10.57	10.59	10.61	10.63	10.66	**36**
37	10.48	10.50	10.53	10.55	10.57	10.59	10.61	10.64	10.66	10.68	10.70	10.72	10.74	10.77	10.79	10.81	10.83	10.85	10.88	10.90	10.92	**37**
38	10.75	10.77	10.79	10.81	10.83	10.85	10.88	10.90	10.92	10.94	10.96	10.99	11.01	11.03	11.05	11.07	11.10	11.12	11.14	11.16	11.18	**38**
39	11.01	11.03	11.05	11.07	11.09	11.12	11.14	11.16	11.18	11.20	11.23	11.25	11.27	11.29	11.31	11.34	11.36	11.38	11.40	11.42	11.45	**39**
40	11.27	11.29	11.31	11.34	11.36	11.38	11.40	11.42	11.45	11.47	11.49	11.51	11.53	11.55	11.58	11.60	11.62	11.65	11.67	11.69	11.71	**40**

To use the table find in the first vertical column the number corresponding to the Quevenne lactometer reading of the milk and follow along the horizontal line in which this appears to the column headed with the per cent. of fat in the milk; the number common to both of these lines is the per cent. of solids not fat in the milk. To find the total solids add the per cent. of solids not fat, as found in the table, to the per cent. of fat.

A SIMPLE FORMULA FOR THE SOLIDS NOT FAT.

Among the numerous formulæ that have been proposed for the calculation of the solids of milk from the specific gravity and per cent. of fat, not one that is sufficiently accurate for general use, is easily applied without tables, and I believe the limited use of such formulæ in this country may be attributed to this fact. This objection does not hold with the formula given below as it is simple enough to be easily remembered and can be quickly applied without tables. At the same time the results obtained by it are, with normal milks containing not more than 6 per cent. fat, nearly as accurate as those by any other formula. For this reason I believe it is well adapted to the wants of dairymen and others who may wish to know more about the composition of milk than is expressed by the amount of fat. This formula has been used the past three winters by students in the Dairy School at the University of Wisconsin and by it they have been enabled, in most cases, to detect the common adulterations of milk, such as the abstraction of fat or the addition of water.

The formula* is as follows:

$$\text{Solids not fat} = \frac{L + .7\,f}{3.8} \text{ and}$$

$$\text{Total solids} = \frac{L + .7\,f}{3.8} + f$$

in which L=Reading of Quevenne lactometer at 60° F. and f=per cent. of fat.

This formula agrees with the more general formula, by

*See 8th Annual Report Wisconsin Agricultural Expt. Station, p. 297.

which the table is calculated, when applied to milks con-containing between 3 and 4 per cent. of fat. For milks containing less than 3 per cent. of fat the formula gives results a trifle too high, and for milks above 4 per cent. of fat a trifle too low, the error, however, will not amount to as much as .1 per cent. with any normal milk containing less than 6 per cent. of fat. If more accurate results are desired the solids not fat as found by this formula may be corrected as follows:

For milks containing less than 1 pct. of fat subtract.........	.09
For milks containing from 1 to 2 pct. of fat subtract.........	.06
For milks containing from 2 to 3 pct. of fat subtract.........	.03
For milks containing from 3 to 4 pct. of fat..........	no correction
For milks containing from 4 to 5 pct. of fat add..............	.03
For milks containing from 5 to 6 pct. of fat add..............	.06

and so on, adding .03 to to the solids not fat, as shown by the formula, for each per cent. of fat above 4 which the milk contains. Corrected in this way the results will agree closely with those obtained by the general formula, for milks or creams containing not more than 20 per cent. of fat.

For ordinary purposes no correction need be applied as the errors of observation, in obtaining the necessary data, would generally be greater than those arising from defects in the formula.

This formula expressed in words gives the following rule for the calculation of solids not fat and of total solids, when the Quevenne lactometer reading and per cent. of fat are known:

Add the Quevenne lactometer reading at 60° F. to seven-tenths of the per cent. of fat and divide the sum by 3.8. The result will be the solids not fat, and this added to the per cent. of fat gives the per cent. of total solids.

The relations which exist in normal milks between the factors entering into the last formula are such that the accuracy of the formula is but slightly affected by chang-ing to the following:

$$\text{Solids not fat} = \frac{L+f}{4}$$

This simple expression gives results with average herd milks which do not vary much more than .1 from those obtained by the general formula given above and is consequently well adaped for use in factories in making preliminary examinations for adulterations.

In general it may be stated that no milk is pure when the Quevenne lactometer reading added to the per cent. of fat does not exceed 32.

The amount of water which has been added to a known sample of milk may be calculated from the solids not fat by dividing the per cent. of solids not fat in the suspected milk by the per cent. of solids not fat in the original sample and multiplying the product by 100. The result will be the number of pounds of milk in 100 pounds of the milk examined. The difference between this and 100 will be the water added. *Example:* The solids not fat in a sample of milk equals 9 per cent. and after water had been added to the milk the solids not fat were only 7 per cent. Then

$\frac{7}{9} \times 100 = 77.7$ per cent of milk in the watered sample, and $100-77.7=22.3$

per cent. of water. That is, 22.3 pounds of water had been added to 77.7 pounds of milk. When the solids not fat in the original milk are not known the legal standard may be taken for this calculation. In states where no legal standard is established, it may generally be assumed that milk containing less than 8.5 per cent. of solids not fat is watered. In all cases, however, when practicable, a sample of milk should be obtained at the farm and compared with the suspected sample.

HOW TO OBTAIN THE APPARATUS DESCRIBED.

The apparatus and chemicals required for making the test for fat in milk may be obtained at the dairy supply stores throughout the country, and parties wishing any of these should apply to them. Sulfuric acid of a specific gravity of 1.82 to 1.83, and powdered bichromate of potassium used for composite tests, may also be obtained at any drug-store.

This Station does not keep any apparatus or chemicals for sale and cannot supply them.

If double sized bottles are desired for testing skim-milk or for the composite test, these should be described in the order and the sockets in the centrifugal machine should be made large enough to admit them.

If it is desired to make the composite test in the ordinary test bottle once in three days, as described on page 239, a pipette holding 5.9 cubic centimeters should be ordered. If a composite test is disired in double sized bottles to be made once a week, a pipette holding 5 cubic centimeters should be ordered.

The cream bottle described on page 233 is designated as cream bottle No. 1.

The ordinary lactometer with scale running from 0 to 120 degrees is kept by all dealers in dairy goods. The Quevenne lactometer is not so generally kept in stock, but dealers will procure the same for any who may desire it.

FACTORY NOTES.

S. M. BABCOCK.

During the past two seasons, 1891 and 1892, students from the Wisconsin Dairy School have been requested to send monthly reports of their work to the Agricultural Department of the University. Blanks have been furnished for this purpose, which provide not only for the details of manufacture, but for the many other points of interest to the dairy students. In response to this request I received over 300 reports from 29 creameries and 52 cheese factories in different parts of the country. From these reports, which represent monthly averages, I have compiled the following statistics which will be of interest to dairymen.

SIZE OF FACTORIES.

Creameries.—Twenty-one creameries report an average in the best part of the season of 35 patrons, and 4,450 lbs of milk per day. Seventeen report an average of 209 cows with 3,829 lbs. milk per day or 18.3 per cow per day. The largest factory had 88 patrons and received 13,800 lbs. of milk per day. The smallest factory had 11 patrons and received 1,325 lbs. milk per day. The average amount of milk from each patron was 126 lbs.

Cheese Factories. Forty cheese factories report in the best part of the season an average of 31 patrons and 5,017 lbs. of milk per day. Thirty-seven of these factories report an average of 263 cows and 5,360 lbs. milk per day, an average of 20.4 lbs. per cow per day.

The largest cheese factory had 98 patrons and received 15,000 lbs. milk per day. The smallest had 5 patrons and received 1,350 lbs. milk per day. The average amount of milk from each patron was 184 lbs.

QUALITY OF MILK AND YIELD.

Creameries. Reports from five creameries that made tests in 1891 show an average of 3.82 per cent. of fat, and nineteen creameries in 1892 show an average of 3.70 per cent. fat in the milk received.

In 1891 the yield of butter from one pound of fat in the milk was 1.113 lbs., in 1892 it was 1.166 lbs. The increased yield in 1892 may be partially attributed to improved appliances, but I believe it is chiefly due to a more general and more intelligent use of the test in locating and avoiding losses. This is borne out by the tests of skim milk and butter milk for the two years. In 1891 the average per cent. of fat in the skim milk was .33, with a range from .1 to .5; in the butter milk the average was .31, with a range from .1 to .6. In 1892 the fat reported in the skim milk ranged from a trace to .3 per cent. with an average of .13 per cent. In calculating this average all reports of a trace of fat have been placed at .08 per cent. The average per cent. of fat in the butter milk for 1992 was .247, with a range from a trace of .6 per cent.

Cheese Factories. In 1891, sixty-eight reports were received from twenty-one factories where milk was tested. These show an average for the year of 3.723 per cent. of fat in the milk used. The lowest monthly average in any factory was 3.25 and the highest 4.6 per cent. fat.

In 1892, 109 reports from twenty-four factories where milk was tested gave an average of 3.624 per cent. of fat for the year. The lowest monthly average from any factory was 3.17 and the highest 4.7.

For the two years the average as derived from 177 reports is 3.662 per cent. fat.

Including both creameries and cheese factories we have received 225 reports which give average per cent. of fat in milk received for one month. Combining them all we have an average of 3.674 per cent. of fat for factory milk. Arranging these by months gives the following results for the season.

Month.	No. reports.	Per cent. of fat.
February	1	4.000
March	3	3.827
April	16	3.442
May	38	3.542
June	36	3.489
July	39	3.559
August	29	3.653
September	25	3 840
October	22	4.003
November	13	4.257
December	3	4.080
Av. for the year	225	3.674

The per cents. of fat from factories in different localities are as follows:

Wisconsin County.	No. reports.	Per cent. of fat.
Columbia	5	3.54
Dane	17	3.72
Dunn	1	3.60
Eau Claire	1	4.00
Fond du Lac	41	3.65
Grant	29	3.73
Green	7	3.69
Iowa	20	3.72
Jefferson	3	3.73
Juneau	1	4.20
Kewaunee	8	3.67
Outagamie	8	3.89
Pepin	4	3 62
Richland	28	3.84
Sauk	8	3.68
Sheboygan	7	3.51
Waukesha	2	3.30
Waupaca	1	3.70
Other states	34	3.46

Eighty-four reports in 1891 give an average yield of one pound of cured cheese from 10.55 lbs. of milk.

One hundred nine reports in 1892 give an average yield of one pound of cured cheese from 10.471 lbs. milk.

In the two years 169 reports gave both the per cent. of fat in the milk and the yield of cured cheese; the average of these is

Fat content of milk = 3.658 per cent.
Milk for 1 lb. cured cheese = 10.473 lbs.
Cheese from 100 lbs. of milk = 9.548 lbs.
Cured cheese for 1 lb. fat = 2.61 lbs.

The following table shows the average yield of cheese, the per cent. of fat and the yield of cheese for pound of fat for each month from April to November exclusive.

Month.	No. of reports.	Per cent. of fat.	Yield of cheese per 100 of milk.	Yield of cheese per lb. of fat.
April	9	3.40	8.983	2.64
May	31	3.51	9.412	2.68
June	29	3.49	9.293	2.66
July	31	3.55	9.220	2.60
August	24	3.65	9.329	2.56
September	20	3.85	10.014	2.60
October	16	4.04	10.583	2.62
November	7	4.26	11.290	2.65

This table shows a very close correspondence between the per cent. of fat and the yield of cheese throughout the whole season, and although complete analyses of the milk are not given, it indicates that the casein of the milk increases with advancing lactation at very nearly the same rate as the fat. The low results during the summer months is undoubtedly due to the greater prevalence of tainted milks at this season, the losses from such milks being always abnormally high.

Arranging these same reports according to the per cent. of fat independent of the season at which the tests were

made, and placing all of the reports which gave milk between 3 and 3.25 per cent. of fat in one group, those with milk between 3.25 and 3.5 per cent. of fat in another group, and so on, the groups varying by .25 per cent. fat, we have:

	No. reports.	Average per cent. of fat.	Lbs. cheese from 100 lbs. milk.	Lbs. cheese for 1 lb. fat.
Group 1, 3 to 3.25 per cent. fat.........	11	3.164	9.046	2.86
Group 2, 3-3.5 per cent. fat.	42	3.377	9.167	2.71
Group 3, 3.5-3.75 per cent. fat..........	59	3.604	9.387	2.60
Group 4, 3.75-4. per cent. of fat.........	18	3.853	9.925	2.58
Group 5, 4.-4.25 per cent. of fat...	25	4.116	10.335	2.5:
Group 6, all over 4.25................ ..	7	4 536	10.813	2.39

This shows a gradual falling off in yield of cheese when referred to the fat as the per cent. of fat increases, and indicates that at the same season of the year the ratio of fat to casein is slightly less in rich milks than in poor milks.

The average yield of cheese when referred to one pound of fat in milk is very nearly the same as was obtained by by Dr. Van Slyke* in New York factories. The yield of cheese for each pound of fat as found by him was 2.75. This refers to green cheese, while the average 2.61 derived from these reports is for cured cheese. If average losses in curing be considered the agreement is surprisingly close.

The average loss of fat reported in whey has been .324 per cent., with a range from .1 to .6 per cent. The loss seems to be practically independent of the amount of fat in the milk and to depend more upon the condition of the milk than any other factor. Tainted and overripe milks are nearly always accompanied by large losses in the whey.

The reports show clearly that the "relative value plan" is growing in favor in both creameries and cheese factories.

*Bulletin 50, New Series, N. Y. Agr. Expt. Station, 1893.

In 1891 only three out of twenty-two cheese factories were reported as paying by the test, and two of these for only part of the season. In 1892 nine factories out of thirty paid by the test. With creameries the improvement was still more marked. Of eight creameries reported in 1891 only one paid by the test, while in 1892, nineteen out of twenty-one were conducted upon this plan. At the present time nearly all of the creameries operated by students of the Wisconsin Dairy School are upon the relative value plan, and I believe that by another season the same will be true of cheese factories.

WORK IN VEGETABLE PATHOLOGY.

E. S. GOFF.

I. EXPERIMENTAL TREATMENT FOR APPLE SCAB.

Experiments in the treatment of apple scab, *Fusicladium dendriticum* (Fckl., were continued during the season of 1891 in the orchard of Mr. A. L. Hatch, of Ithaca, Wis. As in the two preceding years, these experiments were conducted under the auspices of the U. S. Department of Agriculture, and a complete report of them has been published in Bulletin No. 3 of the Division of Vegetable Pathology, pp. 31–36, with plate. Only the conclusions therefore are given here. These are as follows:

(1) One treatment with simple solution of copper sulphate in spring before growth started reduced the amount of scab to a noticeable extent.

(2) The ammoniacal solution of copper carbonate as used in this work was less effective against scab than copper carbonate suspended in water.

(3) The Bordeaux mixture was more effective in this experiment than either form of the carbonate of copper.

(4) Paris green was more efficient in preventing scab and more effective against insects than any of the other preparations used singly or combined.

It should be added in relation to the results secured with Paris green that the conditions were very favorable to its action owing to a very light rain fall which enabled the poison to remain upon the foliage. In ordinary seasons, Paris green is so readily washed off from the leaves that it has comparatively little value as a fungicide.

II. TREATMENT FOR THE APHIS.

An investigation commenced in 1891, in the hope of finding a means of destroying the eggs of the aphis* was continued during the early spring of 1892, but the results proved negative. The kerosene emulsion was further tested upon the Viburnum opulis, but the number of eggs that hatched upon the shrub treated appeared fully as great as on others untreated.

In the laboratory, eggs were treated with various acids and alkalies of varying strengths, but none of these seemed capable of dissolving the shells of the eggs.

Among the materials tried were acetic, picro-sulphuric and picro-nitric acids, carbonate of soda and caustic potash.

From these trials it would appear doubtful that we can combat the aphis from this standpoint.

A spraying with kerosene and water by means of the apparatus described in our last report (p. 162, etc.) just as the leaf buds were unfolding, at which time the aphis eggs were hatching, was fairly successful in ridding the Viburnum opulis of the aphis, and the foliage upon the shrub thus treated had a noticeably fresher appearance for weeks than upon others not thus sprayed.

III. TREATMENT FOR CERTAIN FUNGUS DISEASES.

This article is a summary of the results of many experiments made at our own and other Experiment Stations and is intended to give brief and simple directions for treating some of the more common and more serious plant diseases with which the farmer and fruit grower have to contend. The matter has already been published from our Station as Bulletin No. 34.

The diseases here treated are all of the so-called fungus class. They are caused by microscopic plants that develop on or within the plants they injure, originating from very minute spores, as weeds develop from seeds. The spores, which are produced in very great numbers, find lodgement

*See Report of this Station 1891, p. 174.

in one way or another upon the plants, and under certain conditions of temperature and moisture, germinate, sending their root-like mycelia into the living tissues, consuming the food that their host plants have assimilated for themselves. In due time, these parasites mature a crop of spores, which, finding lodgement upon other plants, serve to spread the devastation.

Treatment Preventive rather than Curative. It should be emphasized that, in the fungus diseases here treated, the parasitic plants that cause the injury develop wholly or in part *within* the tissues of the plants that they infest. As we can apply no beneficial treatment to the interior of a plant, we can do little toward *curing* a fungus disease of this class that is once established upon its host. Our chief hope lies in preventing the germination of the spores of the injurious fungus and thus *excluding* the disease. From this it is clear that the treatment must not be delayed until the plant testifies by its withered or blasted appearance that the dreaded disease is already sapping its life. The preventive applications must be made *before* the spores have had time to germinate, and must be repeated as often as necessary until the danger of infection is past. The observance of this rule is absolutely essential to success in many of our most serious plant diseases.

The Preventive Treatments. From what has been said it is clear that the kind of treatment available for fungus diseases must depend much upon the part of the plant upon which the infecting spores are deposited. When these find lodgment upon the parts of the plant that grow above the ground, and during the growing period, as in the scab of the apple, or the downy mildew of the grape, we must apply our treatment to these parts of the plant, for which purpose we resort to *spraying.* When, however, the infecting spores are planted with the seed, as in the smut of oats and wheat, it is necessary to *disinfect the seed.* These methods of treatment will be considered in their order.

SPRAYING FOR PLANT DISEASES.

In spraying, we aim to distribute water containing a fungicide over the affected parts of the plant we desire to treat. The more thorough the distribution is accomplished, the more likely is the work to prove effectual and the less waste of the liquid that occurs, the more economical is the treatment. It is very important that every leaf of the affected plant or tree shall be wet with the application at least upon its upper surface. An apparatus that projects the liquid in a fine spray and with sufficient force to penetrate the deeper recesses of the foliage, accomplishes the purpose when properly handled, and many styles of force pumps designed expressly for spraying plants, are now manufactured, and are advertised in our leading agricultural papers.

To aid in the selection of a pump, we add that, for orchard work, a form that is supported upon a tripod or is fitted for mounting upon a barrel is convenient, as the pump with its reservoir may be readily carried upon a stone boat or in a wagon. For use upon low plants, as grape vines, currant bushes and potatoes, especially where the rows are planted too near together to admit a stone boat or wagon to pass between them, a knapsack pump, which is arranged for carrying upon the back of the operator, is well adapted.

Fig 63 shows a spraying apparatus designed for orchard work, which has some excellent details that are not found in any one pump that may be purchased in the market, but which have proved eminently useful during several years of spraying experience in the large orchard of Mr. A. L. Hatch, of Ithaca, Wis. The pump, which is of the tripod form, and the barrel for holding the liquid are carried upon a stone boat. By this means they are brought so low down that the barrel is readily filled and the pump easily operated from the ground. The barrel has a large opening for receiving the liquid, over which a strainer, consisting of two or three thicknesses of cheese cloth is placed, and this strainer is arranged so that it can be readily taken off for cleaning. The suction tube is attached to the bottom of the

barrel which makes it possible to draw off all the liquid with the pump. By means of a simple device attached to the pump handle, and which is shown in the illustration, an agitator is operated within the barrel which insures an even distribution of the fungicide material through the liquid. The hose, for distributing the spray, is of extra

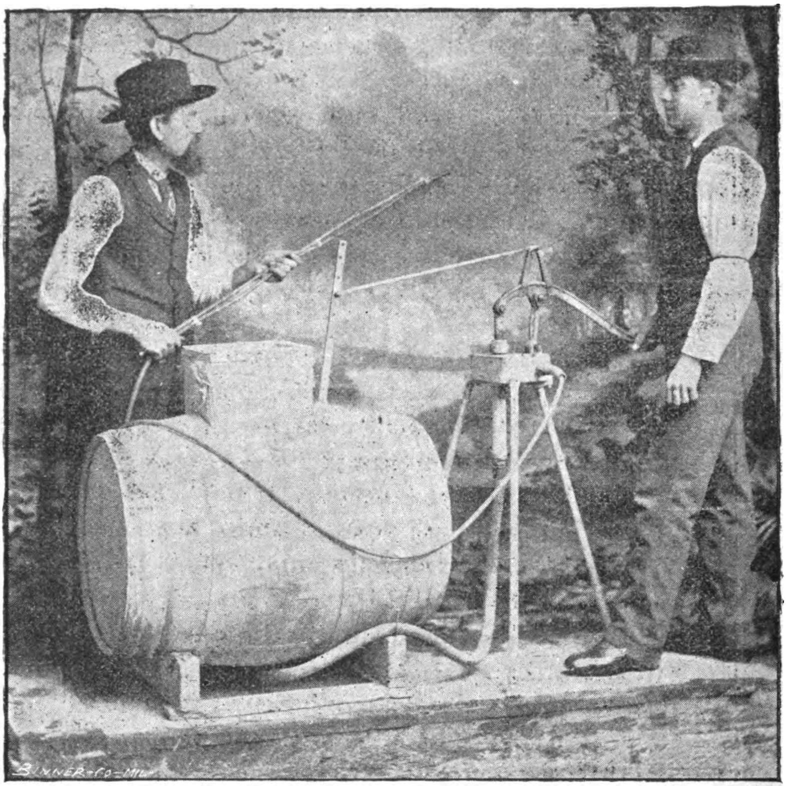


FIG. 63.—A convenient spraying outfit.

strong one-fourth inch rubber tubing, twelve feet in length and is attached to a light reed fish pole. This tube is sufficiently large to supply the nozzle, while it and the pole are so light that they may easily be held out at arms length when necessary. A short section of heavy rubber tubing slipped over the smaller tube at its union with the pump,

greatly protects the smaller tube from breakage at this point.

A pump fitted up like the one here described will cost, exclusive of the stone boat, about fifteen dollars. Those who have but a small amount of spraying to perform may obtain a pump that will answer the purpose for considerable less than this amount. Indeed a few grape vines or currant bushes, or a limited area of potatoes may be treated by means of the common sprinkling pot or a pail and whisk broom.

MATERIALS FOR SPRAYING.

Bordeaux Mixture. The preparation that has proven most valuable as a preventive of fungus diseases is a compound of sulphate of copper (blue vitriol), and lime, diluted with water and is known as the "Bordeaux mixture." To prepare this mixture in quantity, a barrel that will hold water and another wood vessel of at least five gallons capacity are needed. A good recipe for making it is as follows:

In the barrel, dissolve six pounds of sulphate of copper (blue vitriol) in four gallons of water. In the other vessel slack four pounds of fresh lime in four gallons of water. After the sulphate of copper is dissolved and the lime is slacked, stir up the lime and water and pour the mixture into the barrel. Then add fourteen more gallons of water.

It is best to put the sulphate of copper and water in the barrel some days before the mixture is desired for use as it is slow to dissolve. Care should be used to procure *fresh* lime as that which is wholly or in part air-slacked will not answer so well. It is important also to use the Bordeaux mixture freshly made, as it soon loses much of its fungicidal properties on exposure to the air. If a smaller quantity of the mixture is desired the same proportions of the materials should of course be used.

When the Bordeaux mixture is applied with a spraying pump, it should be strained through two thicknesses of cheese cloth, to take out the coarser lime particles, which would otherwise cause trouble by clogging the spraying

nozzle. The mixture will require occasional stirring during the spraying process to prevent the settling of the lime.

Ammoniacal Carbonate of Copper is useful to substitute for the Bordeaux mixture in cases where the latter, by adhering to the fruit, might injure its sale. The formula for this preparation is as follows:

Dissolve one and a half ounces of precipitated carbonate of copper in one quart of commercial ammonia and add this solution to twenty-five gallons of water.

The ammonia should be procured in a glass or earthen vessel and kept tightly corked. It is best to add the solution to the water immediately before spraying, otherwise some of the ammonia will waste by evaporation.

TREATMENT FOR FUNGUS DISEASES.

Scab of the Apple and Pear (*Fusicladium*). This is the disease that causes the scabs or blotches that so often deface the surface of apples and pears. An apple affected with scab is shown in Fig. 64. The scabs not only injure the market value of the fruit but materially reduce its size. The disease also affects the leaves and tends to destroy the vigor of the tree.

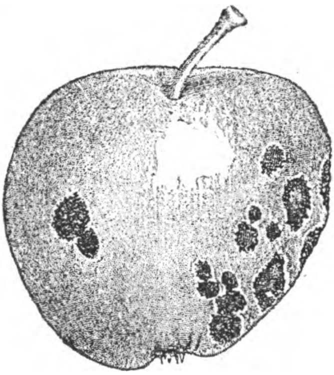


FIG. 64.—Apple affected with scab.

To prevent this disease, spray the trees with Bordeaux mixture, prepared according to the formula given but diluted by reducing it one half with water. Make the first spraying as soon as the leaves appear, a second just after bloom

and a third two or three weeks later. If rains during June are frequent, a fourth spraying should be given the latter part of the month.

The codling moth may be combatted without additional spraying by adding Paris green to the dilute Bordeaux mixture at the rate of an ounce to ten gallons.

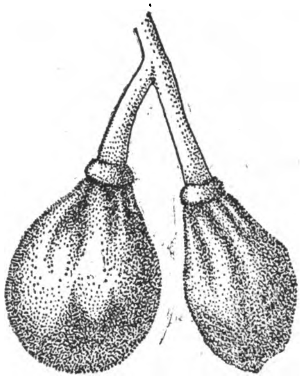


FIG. 65.—Grapes affected with brown rot.

Downy Mildew and Brown Rot of the Grape.—These are the most serious grape diseases prevalent in Wisconsin. The fungus causing them (*Plasmopara viticola,*) attacks the leaves, young wood, flowers and fruit. On the leaves it first appears as greenish yellow or brownish spots on the upper surface, with corresponding spots of a white frost-like growth beneath. Later the frost-like patches may disappear leaving only the brown leaf which soon dries and falls off. On the young wood and flowers, the frost-like growth is more pronounced. This may also affect the fruit, literally covering the berries with the whitish fungus. When the fruit is nearly grown, a brownish purple spot may appear on one side of the berry. Soon the whole fruit turns brown and later becomes soft and wrinkled. This latter stage is what is known as "brown rot."

A portion of a bunch affected in this way, is shown at figure 65.*

*Figs. 64 and 65 are reproduced from "Fungus Diseases of the Grape and Other Plants," by F. L. Scribner, the cuts having been kindly loaned to us by the publishers, the J. T. Lovett Co., Little Silver, N. J.

To prevent these diseases, spray the vines thoroughly as soon as the fruit has set with Bordeaux mixture, made after the formula, without dilution. Repeat the spraying once a fortnight until the grapes begin to color, using Bordeaux mixture until August 1st and after that date the ammoniacal carbonate of copper, prepared according to directions.

The Potato Blight—During the past few seasons, considerable attention has been paid to an affection of the potato popularly known as "blight" or "rust," that has attacked the foliage about midsummer. The disease first appears about the edges of the leaves or where the leaves have been punctured by the flee beetle and the affected parts assume almost immediately, a brown, dead appearance and readily crumble to dust between the fingers. In severe cases, the foliage is totally destroyed and the yield of tubers is largely cut off. Recent experiments have shown that the crop is sometimes damaged by this disease to the extent of more than one half. It is usually most destructive to late potatoes or to the later varieties of those planted early.

This affection has but recently been studied and its precise nature is not well understood. How long it has prevailed in Wisconsin is not known but it probably is not of recent introduction. The disease has doubtless generally been mistaken for normal dying of the potato tops. The trouble should not be confused with the disease that causes the well known and dreaded potato rot, as no connection seems to exist between the two maladies.

Experiments in several states including Wisconsin, during the past three seasons, have shown that the Bordeaux mixture is a preventive of this disease. The first spraying should be made about July 15th, and this should be followed by others two or three weeks apart until the latter part of August. Paris green may be added to the mixture, for destroying the potato beetle if desired. The Bordeaux mixture itself largely prevents injury from the beetle.

The Bordeaux mixture has also been successfully used to prevent the powdery mildew of the apple and the leaf blight of the pear, plum, cherry, gooseberry and currant.

THE SMUT OF WHEAT AND OATS.

Among the most familiar plant diseases with which the farmer has to deal, are the smuts of the small grains, notable of wheat and oats. While these diseases rarely, perhaps never, cause a total loss of crop, they are almost always present in grain fields, and the damage wrought by them is often far greater than is suspected. Careful counts made at various experiment stations indicate that the damage resulting from the preventable smuts in wheat and oats, in fields where the seed is not disinfected, is generally sufficient to have many times repaid the slight cost of disinfection. In view of the simple preventive now known no farmer can longer afford to sow smut-infested grain upon his fields.

The term smut, as ordinarily used by the farmer, includes several distinct fungus diseases. The oat smut is distinct from the smut of wheat or barley. Indeed none of the common smuts of the small grains are capable of living upon more than one kind of grain and at least two different species of smut affect the wheat plant. For the benefit of those who may desire to learn more of these smuts, illustrations of the Loose Smut of oats, *Ustilago Avenæ*, Persoon, and of the so-called Stinking Smut of wheat, *Tilletia fœtens* and *T. Tritici*, are here given.* Plate VII shows the Plate loose smut of oats. Fig. 1 is a head or panicle with all but the uppermost grains smutted; figs. 2 and 3 show small panicles with all the grains smutted.

Plate VIII shows the Stinking Smut of wheat. Fig. 1 shows a completely smutted beardless head and fig. 2 a completely smutted bearded head; figs. 3 and 4 show sound grains of wheat magnified six diameters, fig. 3 in profile and fig. 4 in section. Figs. 5 to 8 show smutted grains; figs. 5 and 6 in profile and 7 and 8 in section.

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* Plates VII and VIII were reprôduced from cuts kindly loaned to us by the director of the Kansas Experiment Station and are from original drawings by Profs Kellerman and Swingle.

PLATE VII.—The loose smut of oats.

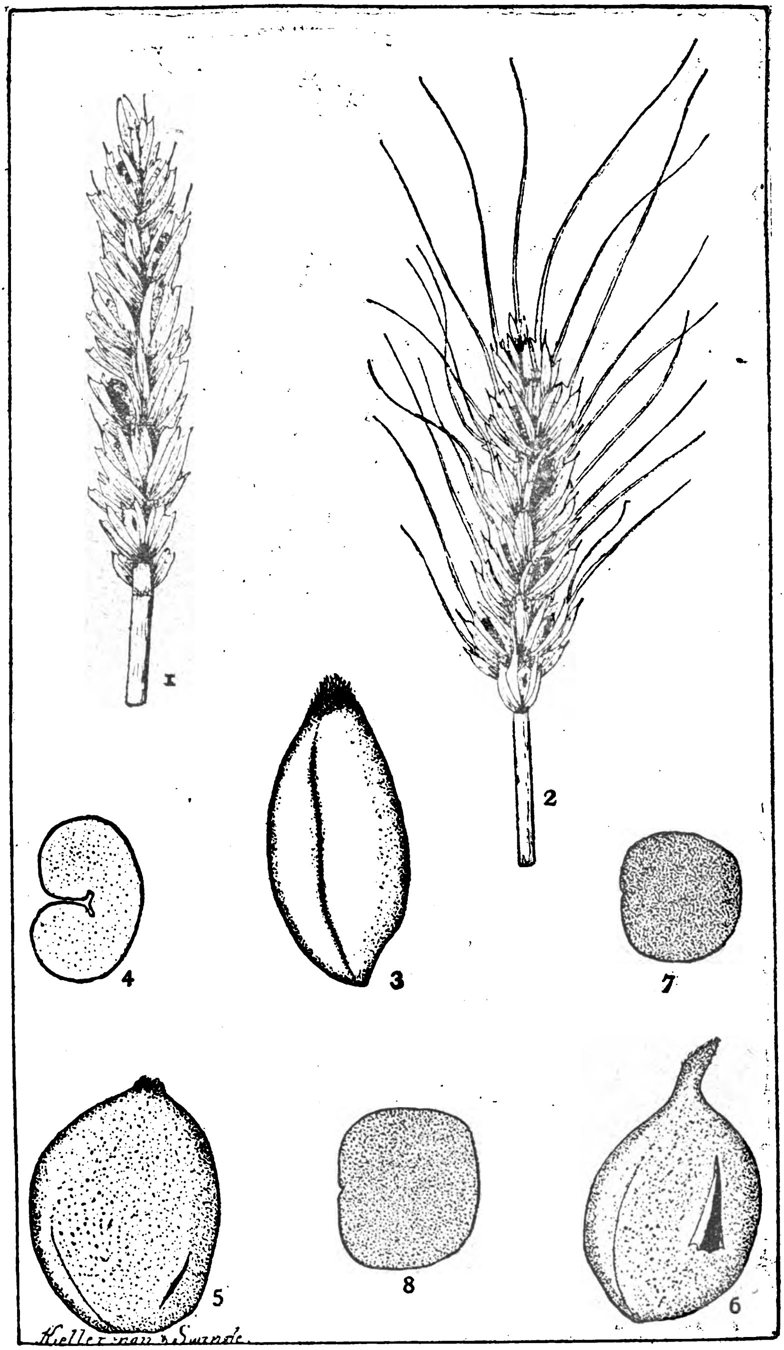

PLATE VIII.—The "stinking smut" of wheat.

The stinking smut in wheat is by no means so conspicuous to the eye in standing grain as is the loose smut of oats. In fact it would usually be overlooked unless careful search were made for it. The infected heads differ but little in appearance from the healthy ones. They are covered in the usual manner by the chaff and while the grains contain but a mass of black spores, they do not usually expose their contents to view. After threshing, however, the smutted grains are readily detected by their dark color and swollen appearance. When crushed between the fingers they emit a very strong and disagreeable odor, hence the name, "stinking smut." Wheat containing many kernels affected with this kind of smut is wholly unfit for flour and is of course unsalable.

The Jensen or Hot Water Treatment for Oats aad Wheat Smut. In the year 1887, Mr. J. L. Jensen, of Denmark, made the important discovery that the spores of most of the smuts affecting the small grains are destroyed by water at a temperature of 130° to 135° Fahrenheit, while the grain is not injured by exposure to this temperature. During the two succeeding years, a practical method of disinfecting grain based on this principle was developed in this country by Messrs. Kellerman and Swingle of the Kansas Experiment Station. We append a discription of this method for the benefit of Wisconsin farmers.

The essential point to be accomplished in this treatment, is to bring every kernel of the grain in contact with water at a temperature of 130° to 135° Fahrenheit. The temperature must not fall below 130° or the spores may not be killed, and it must not rise above 135° or the seed may be injured. By observing the simple method here described no difficulty will be experienced in conforming to these conditions.

In a large kettle, heat a considerable quantity of water to a temperature of 150° to 200°. Then provide a barrel that wlll hold water, and in this pour six or eight gallons of the hot water and temper this with cold water to 133° to 135.° Now put a bushel of the grain in a coarse gunny sack and dip this into the barrel, keeping the bag in motion con-

stantly for five minutes in order to bring all of the grain in contact with the water. Test the temperature of the water in the barrel occasionally during this process, and if it drops to 130°, add hot water in small quantities. To facilitate the agitation of the bag in the water, a lever may be used, balanced over a crotched stick set in the ground.

After five minutes's agitation in the barrel, remove the sack and dip it immediately in cold water to cool off the grain. Then set the bag aside and let it drain for two or three hours, when the grain may be sown broadcast, or spread it thinly upon a floor for further drying if to be sown from the drill. In the latter case, set the drill to half a bushel more per acre than usual to allow for the swelling of the grain.

The farmer need not hesitate to use this method through fear of injuring his seed grain if the directions here laid down are followed with reasonable care. Do not have the water at a higher temperature than 135° at the time of putting in the grain. If the temperature should fall something below 130° while the grain is in the water, let it remain in a little more than five minutes. A good thermometer should be used, but a variation of two or three degrees from the standard will cause no harm if the directions are followed in other respects. In testing the temperature, move the thermometer about in the water for half a minute, and then read it as soon as possible after taking it out.

Tests at several experiment stations have shown that the hot water treatment not only prevents smut, but actually causes an increased yield above the loss that would otherwise have occurred from the smut.

There is a "loose" smut of wheat common in some localities that cannot be prevented by the hot water treatment, nor by any other known treatment. But the loose smut of oats and barley, and the stinking smut of wheat are effectually prevented by the method of disinfecting here described.

EXPERIMENTS IN POTATO CULTURE.

E. S. GOFF.

Except as otherwise noted, the potato crops here reported were grown on spring plowed clover sod, in good condition of fertility, and the seed was planted two and a half to three inches deep, in rows three and a half feet apart. The season proved exceptionally dry and growth was cut short by blight during the latter part of the summer.

SHOULD SCABBY POTATOES BE PLANTED.

An experiment was made to discover the influence of badly scabbed seed upon the yield, and upon the amount of scab in the crop. The variety used was Rose Seedling. The scabby seed tubers were so badly affected that almost the whole surface was roughened, and but a few of the eyes were visible. Eighteen rows 143 feet long were devoted to this experiment, each alternate row being planted with the scabby seed, and the remaining rows with seed nearly or quite free from scab. When the crop was harvested, a sample amounting to two bushels was selected both from the rows grown from the scabby and from the clean seed, and these potatoes after being washed, were assorted into three qualities with reference to the amount of scab as follows:

First quality—tubers free from scab.

Second qualitity—tubers with some scab spots, but these not sufficient in size or number to materially affect their market value.

Third quality—tubers more affected.

The results appear in the following table in which the total yield from the nine rows from each class of seed is given in pounds and at the right is given the percentage of the sample from each class of seed that fell into the three qualities above noted.

Table showing the effect of using scabby seed potatoes

	On Yield.		On amount of scab in crop.		
			Per cent of tubers		
	Merchantable.	Small	Free from scab.	Slightly scabby.	Badly scabbed.
	Lbs.	Lbs.			
Seed free from scab.	435¼	42½	26.70	56.81	16.49
Seed very scabby	184¼	15⅛	19.35	51.08	29.57

As appears from the the table, the scabby seed seems to have greatly reduced the yield. This result was largely due to a small vegetation in the rows grown from the scabby seed. Many hills failed entirely, and in many others, the stalks were much fewer in number than in the rows from the clean seed, and the growth was noticeably weaker throughout the season. It would appear that the scab fungus is capable of consuming the eyes of potatoes to an extent that will prevent their germination.

The results of this experiment appear more clearly in the following graphic diagrams.

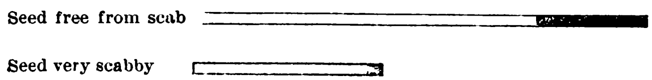

FIG. 66. Showing the comparative yield of potatoes from scabby and clean seed. [The black portion represents the small potatoes.]

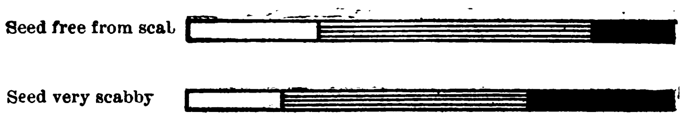

FIG. 67. Showing the comparative amount of scab in the crop grown from scabby and clean seed.

[The white part represents the portion of the crop free from scab, the lined part the portion slightly scabby, and the black part the portion very scabby.]

CAN POTATO SCAB BE PREVENTED BY TREATING THE SEED WITH SULPHUR ?

The claim has sometimes been made through the agricultural press that potato scab may be wholly or in part prevented by the use of sulphur in the hill, while some who have made the experiment have reported failure. The latest investigations indicate that the scab is due to injury caused by a parasitic fungus, and since sulphur is known to destroy many fungi, it was thought well to test its efficacy for the potato scab. Accordingly, a late planting of potatoes, consisting of several different varieties, was subjected to the experiment. One-half of the hills in each row were treated with sulphur, leaving the other half without treatment as a check. The sulphur was tried in two slightly different methods. In one the seed tubers were dipped in water and then rolled in flowers of sulphur; in the other the seed tuber was first dropped and then before covering it, half a teaspoonful of flowers of sulphur was sprinkled over the tuber, and upon the soil about it over a circle of six inches in diameter. The planting was done June 9, and the crop was harvested October 7, at which date the tubers were assorted into three qualities as described in the preceding paragraph.

The results of this assortment appear in the following

Table showing the effects of using sulphur to prevent potato scab.

	TREATED WITH SULPHUR.			NOT TREATED.		
	Per cent. of Tubers			*Per cent. of Tubers*		
	Free from scab.	Silght-ly scabby.	Badly scabbed.	Free from scab.	Slight-ly scabby.	Badly scabbed.
Seed tubers wet and rolled in sulphur......	77.74	17.5	4.76	64.09	25.58	10.33
Sulphur sprinkled over seed tuber and upon the soil about it	57.53	28.82	13.45	51.80	31.49	17.21

The figures indicate that the sulphur proved in some degree beneficial in reducing the amount of scab, but that it

was far from being a complete remedy. The following graphic diagram, based on the average of the two experiments, more clearly illustrates the influence of the sulphur.

Seed tubers treated with sulphur

Seed tubers not treated

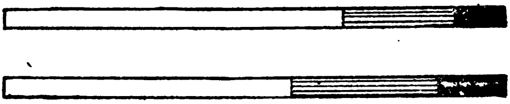

FIG. 68. Showing influence of sulphur in reducing potato scab. The white portion indicates the tubers free from scab, the black those badly affected, and the lined portion those slightly affected.

THE EFFECT OF REMOVING THE "SEED END" OF SEED POTATOES UPON THE CROP.

The results of experiments on this subject are given in the Reports of this Station for the years 1890 and '91. These experiments have been continued during the past two seasons, and as it appears unnecessary to continue them further, we present the results of the past two years in this report, together with a summary of all the trials.

In 1891, the test included 26 rows each 143 feet long. These were planted on May 9, with regular tubers of medium size, of the Rose Seedling variety. In the first and each alternate row, amounting to thirteen rows in all, about three-fourths inch from the "seed" or distal end of each seed tuber was cut off, while in the remaining thirteen rows the tubers were planted entire. The weight of the seed tubers of each row was recorded before planting, the average for the rows in which the seed end was removed being 20.19 pounds, (after removing the seed end) and for those planted with entire seed 20.8 pounds.

The crop was harvested October 10 to 12, when it appeared that in ten of the thirteen pairs of rows, the row planted with entire seed yielded more than the row planted with seed from which the end was removed. The total yields from the two classes of seed were as follows:

	Merchantable.	Small.
13 rows, seed planted entire	1,899¾ lbs.	229¼ lbs.
13 rows, seed ends removed	1,867¼ lbs.	248¾ lbs.
Difference in favor of entire seed	32½ lbs.	

The trials in 1892 included 26 rows each 50 feet long, planted on fall plowed sod of some years' standing and in good condition of fertility. The seed was of regular, medium size planted two feet apart in rows 3½ feet apart, on May 16.

Twenty of the rows were of the Snowflake variety, and the remainder were of the Rose Seedling.

The first and each alternate row were planted with entire seed, and the remaining rows with seed of which the seed end had been removed as already described. In this trial, the tubers planted in each pair of rows weighed exactly alike, after the removing of the seed ends from the tubers of one of the rows. The crop was harvested September 20, when it appeared that, as in the preceding year, in ten of thirteen pairs of rows, the row planted with entire seed exceeded the other row in yield. The total yields from the two classes of seed, and from the two varieties were as follows:

	Merchantable.	*Small.*
10 rows Snowflake, seed planted entire	180¾ lbs.	57¾ lbs.
10 rows Snowflake, seed end removed	16 ¼ lbs.	67 lbs.
Difference in merchantable potatoes in favor of entire seed.	13½ lbs.	
3 rows Rose Seeding, seed planted entire	60 lbs.	9½ lbs.
3 rows Rose Seeding, seed end removed	53¼ lbs.	13¼ lbs.
Difference in merchantable potatoes in favor of entire seed.	6¾ lbs.	

SUMMARY OF FOUR YEARS' TRIALS.

Bringing together the results of four years' trials, as in the following table, furnishes an amount of data that better warrants us in forming conclusions.

YEAR.	YIELD FROM ENTIRE SEED		YIELD FROM SEED WITH SEED END REMOVED.		DIFFERENCE IN FAVOR OF ENTIRE SEED.	
	Merchantable.	Small.	Merchantable.	Small.	Merchantable only.	Total Yield.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1889*	132.1	117.4	97.7	120.7	34 4	31.1
1890*	1,813¼	693¾	1,744	679	69¼	84
1891	1,399¾	239¼	1,367¼	248¾	32½	23
1892	240¾	67¼	220½	80¼	20¼	7¼
	3,585.85	1,117.65	3,429.45	1,128.7	156.4	145.35

*See report of this Station, 1890, p. 212; 1891, p. 186.

It thus appears that in each of the four seasons during which the trial has been conducted, the entire seed has given the larger yield, the difference, which will appear more clearly from the accompanying diagram, amounting on the average to something more than four and one-half per cent. It is noticeable also, that in but one of the four seasons did the yield of small tubers from the entire seed equal that from the seed having the seed end removed.

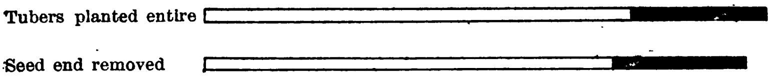

FIG. 69. Showing th effect of removing the "seed-end" upon the crop—average of four season's trials.
[The black portion represents the small potatoes.]

This fact would appear to disprove the only argument that I have heard advanced in favor of removing the seed end, viz.: that the planting of a cluster of eyes at the distal end of the tuber tends to multiply shoots, and thus to increase the percentage of small tubers.

The only conclusion warrantable from these trials is, that under the conditions in which they were conducted, *the removal of the seed end was detrimental to yield.*

This result is in accordance with analogy. The potato tuber is not a root, but a thickened underground stem, of which the so-called "seed end" corresponds to the apex. It is a well recognized fact that the terminal bud of a shoot is the strongest one, and the removal of this bud tends to check the vigor of growth. The seed end of the potato tuber, sprouts first in spring, and when the tuber is planted whole, the first and the strongest shoot almost always proceeds from the seed end. Theoretically, the continuous removal of the most vigorous buds would tend to diminish vigor and productiveness.

STRAWBERRIES.

E. S. GOFF.

I. A BREEDING EXPERIMENT WITH STRAWBERRIES.

The marked decline of the Wilson strawberry during recent years is well known to all who have been familiar with this fruit as grown in this country during the last two decades. Yet a few growers, among whom may be named Mr. J. M. Smith, of Green Bay, Wisconsin, continue to have excellent success with this time-honored variety. Indeed, Mr. Smith claims that no recent variety among many he has tested fully equals the Wilson in yield. He has long ascribed his success with the Wilson to the fact that he invariably takes his plants for setting from beds set the preceding spring, and which have not borne a crop of fruit.

Certain experiments made at our Station lead to the belief that Mr. Smith is correct in this reasoning. The results of these experiments seem to show that the so-called "spot disease" or blight of the strawberry, caused by the fungus *Ramularia Tulasnei*, may produce an enfeebled condition of the plant from which it does not rally for at least several generations. It is well known that the Wilson strawberry is very subject to this disease, but that plantations do not often suffer much from it until the year after planting.

In the spring of 1889 Mr. Smith kindly sent to our Station fifty plants of what he thought his most vigorous Wilson strain. These were divided into two lots of twenty-five plants each, and planted in two small beds about four rods apart. Both beds did well during the first summer, and yielded a good crop of fruit in 1890. But after the fruiting season, one of these beds was badly affected with blight, while the other, from some unknown cause, was

nearly or quite exempt from it, and the same was true in the summer of 1891, the same bed being nearly free from blight both seasons. The result is that but forty-four plants in the diseased bed survived the winter of 1891–2, while 231 plants survived in the other bed. If there is any difference in the environment of the two beds, the one that has suffered so badly from blight would seem to be the more favorably located, hence no other cause can be ascribed for the failure of this bed than the disease from which it has suffered.

In order to test the validity of Mr. Smith's theory, as noted above, a new bed of young plants taken from the bed set the previous spring, and which consequently has not borne a crop, has been planted each spring. With these have been compared other beds formed of young plants from the diseased bed mentioned above, and also from other beds that, while not especially diseased, had borne at least one crop of fruit. A record of yields from these plantings has been kept, but as the exact number of healthy plants in the different beds was not noted at the time the fruit was gathered, the figures based on crop alone might be very misleading. It will be more just to compare the vigor of the different plantings by noting the number of surviving plants in the spring of 1892.

In the spring of 1891 a bed of sixty-five young plants was made, the plants being taken from a bed set the previous spring, and which had been set in the spring of 1890 from the healthy bed grown from Mr. Smith's plants set in 1889. In other words, the ancestors of these sixty-five plants had been free from disease and had not borne a crop, at least since 1888, and, as Mr. Smith affirmed, for many years previous. This bed contained in the spring of 1892, 332 strong plants, besides some others that have suffered from the winter, or a fraction over five and one-tenth plants to each one set. It should be remarked here that August and September of 1891 were extremely dry, which explains the meager growth of plants. Twenty-six young plants from the blighted bed above mentioned were set in the spring of 1891 in two short rows adjoining the sixty-

five plants just mentioned. The vigor of this blighted bed had become so much reduced that a larger number of young plants could not be obtained; these twenty-six plants are, therefore, from parents blighted severely for two generations, and yielding a crop of fruit the summer previous. But forty-three plants have survived the winter from this bed, or a little less than one and seven-tenths plants to each one set last spring.

Another small bed of thirty-nine young plants was set in the spring of 1891 adjoining the one just mentioned. For this the plants were taken from a bed that was set in 1889, and hence had borne a crop of fruit, but which had not suffered much from blight. In this bed a fraction less than four plants have survived the winter for each plant set. Recapitulating, then, we have:

Plants with ancestry free from disease, and not weakened by bearing, five and one-tenths surviving plants for each plant set.

Plants with ancestors suffering from disease two preceding generations, and further weakened by bearing, one and seven-tenths surviving plants for each plant set.

Plants with ancestry nearly free from disease, but having borne one crop of fruit, four surviving plants for each plant set.

The above three lots of plants were all set on the same day and have received exactly the same treatment.

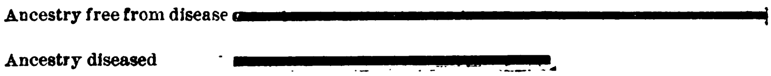

FIG. 70.—Showing comparative growth of plants from healthy and diseased parentage.

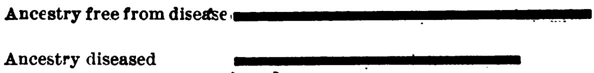

FIG. 71.—Showing comparative yield of plants from healthy and diseased parentage.

These results are rendered the more intelligible by the annexed illustration. The first two lines show the comparative *growth of plants* between the bed grown from healthy plants not weakened by bearing, and the average

of the other two beds. The second two lines show the comparative *yield of fruit* from the same.

The difference in fruit product is less marked than that of plant product, but it is sufficient to be of decided moment.

The differences of vigor manifested in the above plantings are greater than we should usually expect from different varieties of the strawberry similarly treated. The lesson seems clear enough. It is unwise to plant a new strawberry bed from a plantation that has suffered from the attack of Ramularia. The young plants from such a bed, whether they develop the disease or not, are reduced in vigor, and are not likely to prove satisfactory. It would appear that Mr. Smith's fine success with the Wilson strawberry may be more due to his always having grown his plants from parents that were free from disease, than from the fact that they had not been permitted to bear.

It seems not improbable that in fruits like the strawberry better results may be gained through methods which aim at promoting the vigor of the varieties we already have, than in continuing the production of new seedlings, the method of improvement usually adopted.

II: NOTES ON STRAWBERRIES.

The months of May and June, 1892, were so excessively rainy that the growth and maturity of strawberries were abnormal. This fact, coupled with the unusual drought of the season of 1891, would probably render numerical data in regard to varieties misleading. The yields of the different varieties were carefully noted as usual, but it is thought better to give our general impressions in regard to them than to offer more exact data.

The plants of all were set in the spring of 1891, except as otherwise noted.

All of the varieties were grown on rich ground, and received good culture, but the covering in the autumn of 1891 was delayed longer than usual, and doubtless longer than the best welfare of the plants would have dictated.

Alabama.—Ripe June 25; berries firm, of fair size, and

quality; plant only moderately productive, foliage evidently inclined to blight.

Aroma—Ripe June 20. Very productive, of uniform large, finely colored fruit of superior flavor, but somewhat lacking in firmness; very promising, at least for home use.

Banquet.—Set fall of 1890. Ripe June 24. Plant feeble in growth, but free from blight; moderately productive of regular fruit of medium size and rich meaty quality. It is worthy of a place in the amateur's garden.

This variety is of interest because of its parentage, being a claimed cross between the wild Fragaria Virginiana, and one of our cultivated varieties.

Bessie.—Ripe June 20. Plant lacking in vigor, producing a moderate crop of firm, well colored, uniform fruit, of good quality; the foliage inclines to blight.

Boynton.—Ripe June 19. Plant very vigorous and productive, but the fruit is small, and lacks quality, though rather firm. Worthy of further trial.

Crawford.—Ripe June 25. But few plants of this variety survived. These bore some very fine fruit of good size and color and of fair quality. The foliage was healthy and vigorous; regarded as one of the most promising.

Cruse's No. 9.—Ripe June 26. Plant vigorous and free from blight; fruit regular, of good size and quality, firm enough for near market; promising.

Cyclone.—Set fall of 1890. Ripe June 28. Plant of moderate vigor, productive; fruit of fair size and quality.

D and D.—Ripe June 20. Plant vigorous, free from blight, productive of fine, large fruit of fair quality; promising.

Edgar Queen..—Set spring of 1890. Ripe June 23. Similar to the Sharpless; plant vigorous and healthy, very productive of large, often irregular fruit of fair quality.

Lovett's Early.—Set fall of 1890. Ripe June 23. Plant rather vigorous and productive; fruit good in size, color and quality; foliage free from blight. It should not be called "early."

Martha.—Ripe June 22. Plant vigorous and productive;

fruit of good size, but inclined to grow irregular, very firm, of poor quality except when fully ripe, when it is very rich; color nearly as deep as that of Warfield. The calyx inclines to turn brown and the foliage shows signs of blight. This has considerable promise as a market variety.

Michel's Early.—Ripe June 18. Plant very vigorous, but lacking in productiveness, fruit of fair size and quality. The first fruits ripened with those of Van Deman, but the latter gave the larger early pickings, and was more productive as a whole.

Middlefield.—Ripe June 22. Plant moderately vigorous, productive; fruit regular, of good size and quality, and sufficiently firm for market. The foliage shows signs of blight.

Oliver.—Ripe June 29. Plant vigorous, but not productive. Its value, if any, will be in its extreme lateness. The fruit is fine in appearance.

Pearl.—Ripe June 22. Plant moderately vigorous; fruit very uniform, of fair size, good color, and quality. The foliage shows signs of blight; rather promising.

Saunders.—Ripe June 25. Plant moderately vigorous, and productive; fruit very large, of superior color, but inclines to have a green tip, and the calyx sometimes browns before complete ripeness.

Shuster's Gem.—Set spring 1890. Ripe June 21. Plant quite productive; fruit of good size, very uniform, showy in appearance, but lacking in firmness and quality.

Van Deman.—Set spring of 1890. Ripe June 18. This variety proved less productive than in 1891. The plants bloomed profusely, but many of the later blossoms failed.

Yale.—Ripe June 25. Plant moderately vigorous, quite productive; fruit large, often very irregular, firm and of good color, but has too many white tips to be valuable. The foliage inclines to blight.

Seedling from Geo. Williams, of Waupaca, Wis. Ripe June 23. Plant of the Wilson type, lacking in vigor and inclined to blight; productive of small, firm, deep red fruit.

SUGAR BEET EXPERIMENTS IN WISCONSIN DURING 1891 AND 1892.

F. W. WOLL.

The subject of sugar beet culture in Wisconsin has been studied for the last three years at this Station, the work being performed under the general direction of the U. S. Department of Agriculture, which also rendered financial aid. The object of the investigation was to determine in how far the climate and soil of Wisconsin are adapted to sugar beet culture, with the view of preparing the way for sugar beet factories in our midst. The line of investigation during the past two years was, first, to grow different varieties of beets at the University farm so as to obtain additional data as regards richness and yield of sugar beets with us, the cost of cultivating and harvesting the crop, etc., and second, to distribute sugar beet seed among farmers in different parts of the state, and in that way to investigate the adaptibility of each region of the state to sugar beet culture and especially as to the quality and yield of the beets grown. The report is naturally divided into two parts, (a) report of experiments at this Station, and (b) report of analysis of beets from farmers in different parts of the state.

A. SUGAR BEETS AT THIS STATION IN 1891 AND 1892.

I. Season 1891.

A piece of land of very nearly two acres was set apart in the spring for sugar beets. The plot slopes somewhat to the west and is light clayey loam, becoming more sandy at the east end. As a consequence the eastern portion is considerably drier and would suffer more in case of drouth

which also proved true during the exceedingly dry summer of 1891. The meteorological data for this place for the months May-October, inclusive, are given in the following table; for the sake of comparison the total rainfall for the same months last year, and also the normal rainfall (average for twenty six years) are given in the table :

Meteorological data for May-October, 1891, *for Madison, Wis.**

	May.	June.	July.	Aug'st.	Sept.	Oct.	Tot'l.
Total rainfall, inches	1.44	3.69	2.67	1.41	.38	1.49	11.02
Normal rainfall	3.54	4.42	4.19	3.28	3.35	2.87	21.65
Rainfall for 1890	5.03	7.72	1.81	4.23	2.62	4.59	25.00
Maximum temperature, °F	78	88	86	92	90	83	......
Minimum "	32	44	48	46	35	19	......
Mean "	56	67.2	66.6	68.4	67	45.4	......
Normal mean "	57.8	67.2	72.7	69.4	61	48.5	......

It will be noticed that the precipitation for 1891 for the summer months was only 11.02 inches, or about half of normal and less than half of the rainfall for 1890 during the same months. Up to July 7, the prospects for a large yield were most promising; between July 7 and August 26, there was not more than one good rain, and as a result the beets suffered greatly from drouth from this time on; as August, September and October were very dry, the growth of the beets was checked, and a small yield of beets, to some extent abnormally rich in sugar, was the result. May, July, August and October were colder than the normal, while September was considerably warmer. With a proper supply of moisture there is, however, little doubt but what a good crop of beets would have been harvested.

VARIETIES PLANTED.

The following eleven varieties were planted on May 26 and 27: Le Maire's Richest, Simon Le Grande, Vilmorin, Kleinwanzleben, Bulteau Desprez, Desprez B. & R., La

*From observations made at Washburn Observatory.

Plus Riche, F. Krœmer, O. B. S. & Co., French, German. The first nine varieties were obtained from Oxnard Beet Sugar Co., Grand Island, Nebraska, and the last two varieties from the U. S. Sugar Experiment Station, at Schuyler, Nebraska.

In all 183 rows were planted. The length of each row was 190.6 feet, and the distance between the rows thirty inches; the seed was planted thicker than during 1890; after last thinning the beets stood 4 to 6 inches apart in the rows. From 14 to 22 rows were planted of each variety, these being planted in the order given above, starting from the west end of the plot. The plot was cultivated on June 10–11 with wheel hoe, June 15 with narrow tooth single cultivator; June 22–26 the plants were thinned and hoed, and a horse cultivator run through the rows. At this time the plants were about three inches high. The horse cultivator was run through the rows again on July 2, 14 and 31, and the weeds in the rows were destroyed by hand hoeing on July 20–23 and August 1. The harvesting was done by plowing a furrow close up to the beets; after thus laying them bare they were easily pulled and thrown in a pile. After all beets were thrown in piles they were topped and drawn by team to the farm root cellar after having first been weighed. A basketful of each load was taken out to be washed, and the per cent. of dirt adhering to the beets was thus ascertained.

The following table gives the work expended in growing the crop of beets, and also the cost, estimating the wages for a man 10 cts. an hour, for man and horse 15 cts. and for man and team 25 cts. per hour:

Cost of growing a crop of beets from a two acre field.

Plowing and preparing the land (allowed)	$2.00
Planting and cultivating the crop:	
304 hours' time for 1 man	30.40
22 hours' time for man and horse	3.30
Harvesting and hauling the crop:	
111 hours' time for o e man	11.10
28 hours' time for man and team	7.00
Total	$53.80

From this field we obtained a little more than fourteen tons of washed beets (see below), which would make the total cost of growing and harvesting a ton of beets $3.76, allowing the tops, which yielded more than four tons from the plot, to pay for rent of land, cost of seed and wear of machinery. Last year our beets yielded more than twenty tons per acre on an average; this yield may be considered somewhat above the average for good land and cultivation, but if we take fifteen tons as an average yield per acre, we get the cost of raising and harvesting one ton of sugar beets $2 46, assuming the cost of harvesting and hauling the beets double the amount charged in the above table. The average price per ton of beets during the past season was in Nebraska $3.50, in California $4.00, in Utah $4.50. With the average price of $4.00 paid for the beets the net income from one acre would be $23 00. Doubtless the cost of growing the crop could be considerably reduced by growing the beets on a larger scale and by the application of machinery that will successfully pull the weeds in the rows between the beets; on the other hand, the cost of hauling the beets would be larger with a greater distance to the factory, an item that would easily swallow up all profit, if the distance be too great.

EXAMINATION OF BEETS GROWN.

The beets were sampled and analyzed September 26, 1891, and also at harvesting time, October 26th. Three beets were selected for analysis, washed and dried, a quarter section of each beet cut and grated together, the pulp put in a linen bag and the juice pressed out. The specific gravity of this was then observed, and the clarified juice polarized. At harvesting time, two or three different samples of each variety were taken, and the results averaged. The sugar in the beets was determined in these samples by the alcohol method of Tollens-Rapp-Degener (Koenig, Unters. landw. wicht. Stoffe, 1891, p. 436.) The results of the analysis are given in the following table:

Sugar Beets grown at the University Farm, Season 1891.

Name of Variety.	Av. weight of beets.	Solids in juice.	Sugar in juice.	Purity Coeff.	Sugar in the beets.
Samples taken at harvesting time, October 26:	Lbs.	Per cent.	Per cent.		Per cent
Le Maire Richest.........	1.28	19.72	16 97	86.1	14.54
Simon LeGrand...	1.08	18.52	14.99	81.0	13.27
Vilmorin	.71	21.07	17.95	85.2	15.63
Kleinwanzleben............	.69	21.77	18.78	86.3	15.70
Bulteau Desprez	.61	20.69	16 84	81.4	15.67
Desprez	.73	21.38	17 28	80.8	14.87
La Plus Riche.................	.57	22.23	18.24	82.0	15 50
F. Kroemer.......	.49	22.79	19 35	84.9	15.99
O. B. S. & Co....	.53	22.25	17.81	80.0	15.61
French....	.70	21.25	17.37	81.7	16.17
German...	.87	23.86	20.53	86.1	17.56
Av. of Analyses, Oct. 26...	.71	21.41	17.83	83.3	15.50

The quality of the beets did not improve after September 26, and it is not likely that the yield was increased perceptibly during the month of October, owing to the extreme dryness of the soil. The beets were very small, averaging only about 11 ounces for all the varieties; the average per cent. of sugar (sucrose) in the juice at harvesting time was 17.83 per cent., ranging from 14.99 to 20.53 per cent. The average per cent. sucrose in the beets was 15.50 per cent., with 13.27 and 17.56 per cent. as lowest and highest limit. By dividing 15.50 by 17.83, we find that the beets contained 86.9 per cent. of juice on an average, showing that the dry season produced beets with an unnaturally high sugar content and with a low percentage of juice.

It will be noticed that the percentages of sugar increase as we go down in the table, that is, with the beets growing farther east on the plot; we saw that the soil was drier and perhaps also poorer in the eastern part of the field than in the western; the beets were smaller in size and richer in sugar the farther east we go in the field; as a rule, size and

sugar content of the beets stand in inverse ratio to one another.

YIELD OF BEETS.

The following table will give the necessary data with reference to the yield of beets and of tops from the plot, and the calculated yield of beets and of sugar per acre for each variety.

Yield of beets and of tops.

No. of rows.	Name of Variety.	Beets from Plot.	Tops from Plot.	Pct. dirt on beets.	Washed beets per acre.	Sugar per acre.
		Lbs.	Lbs.		Lbs.	Lbs.
22	Le Maire's Richest	4,828	1,570	8.1	17,651	2,566
18	Simon Le Grande	4,204	1,334	4.4	10,473	1,390
16	Vilmorin	2,994	654	9.7	15,491	2,421
14	Kleinwanzleben	2,804	1,008	13.1	15,960	2,506
14	Bulteau Desprez	2,624	772	14.7	14,662	2,298
20	Desprez	3,531	768	8.9	14,758	2,195
18	La Plus Riche	2,780	632	13.3	12,280	1,903
16	F. Kroemer	2,183	504	12.5	10,973	1,755
16	O. B. S. & Co	2,355	568	12.4	11,745	1,833
14	French	1,945	466	12.4	12,284	1,986
15	German	1,701	460	14 8	8,860	1,555
	Total from plot (1.915 acres)	31,957	8,736			
	Average per acre				14,677	2,267

The beets yielded seven and one-third tons to the acre and a little more than one ton of sugar to the acre. In 1890, under favorable conditions of weather, the yield was 15 to 26 tons per acre, with an estimated yield of 2 to 3½ tons of sugar per acre. Owing to the extreme drouth, the like of which, according to the testimony of many old settlers, has not been seen for a generation with us, the beets yielded less than a half crop. The yield of seven tons to the acre may, therefore, be considered the very lowest returns which will be obtained with us when good cultivation and care are bestowed on the beets.

No comparison can be made between the different variet-

ies as regards quality or yield, the difference between the different parts of the field being greater than that between the different varieties; the varieties being under the most favorable conditions (on the lowest ground, which contained most moisture) gave the largest yield per acre of both beets and sugar.

II. Season 1892.

Two plats of about one-third acre each, were set apart for sugar beets during the spring of 1892. The soil was a light clay loam, that of the eastern plat being somewhat more clayey. Rutabagas were grown on both plats during 1891. The eastern plat (plat II) received 100 lbs. of Crocker's bone phosphate, as the soil here was much exhausted owing to continuous cropping with prickley comfrey for four years; the other plat had been in clover and in grasses during this time, no manure was applied on this plat (plat I.) The ground was plowed six inches deep. About one-half of plat I was subsoiled six inches, and the same varieties of beats were grown on both halves of the plat.

The following are the main meteorological data for Madison for the summer months:

*Meteorological Data for Madison, Wis, May-October, 1892.**

	May.	June.	July.	August	September.	October.	Total
Total rainfall. inches	6.98	7.61	2.32	3.43	3 29	.36	23.99
Normal rainfall, inches	3.51	4.42	4.19	3.23	3 35	2.87	21.65
Max. daily temperature, °F	72.6	86.2	88.0	88.2	81.1	75.8	......
Min. daily temperature, °F	33.5	46.0	50.0	51.0	45.0	25.8	......
Mean daily temperature, °F	52.0	64 8	71.1	69.7	61.2	51.2	......
Normal mean daily temperature, °F	57.8	67.2	72.7	69.4	61.0	48.5	......

* From observations made at Washburn Observatory.

Owing to the extreme wet weather in May and June and consequent late season the sugar beet seed was not planted until June 11th. Five different kinds of seed were planted, viz.: Vilmorin improved sugar beet seed (Vilmorin I in this

report); the same variety, high grade seed imported during the spring 1892 by the United States Department of Agriculture, (Vilmorin II in this report); Kleinwanzleben, Desprez Richest and White Imperial. The seed of the first four varieties was obtained from Washington, D. C., through the courtesy of Dr. H. W. Wiley, chief chemist. The last given variety was the same as distributed during 1891 by this station to farmers in the state.

Twelve or thirteen rows were grown of each variety, the sub-soiled rows of plat I being 78 ft. long, and the other rows of plat I 60 ft. long. The rows of plat II were 153 ft. long; all rows ran east to west and were 30 inches apart; the beets stood about 6 inches apart in the rows after last thinning. The following statement shows the cost of growing the crop. As before the wages for one man are estimated at 10 cents an hour, for man and horse 15 cents, and for team and man 25 cents an hour.

Cost of growing sugar beets, season 1892.

174½ hrs. time for one man	$17 45
8 hrs. time for man and horse	2 70
25 hrs. time for man and team	6 25
Total	$26 40

This includes all steps, from plowing and preparing the land to the hauling of the beets and storing them in the root cellar. In all, 14,505 lbs. of washed beets were obtained from the two plots (see below), or the total cost of growing a ton of beets amounted to $3.64. Season 1891 (see page 293), the cost was $3.76. It is evident that the expense of growing the crop would be greatly reduced if a larger area was planted; but it would seem that the profits from growing sugar beets would be meager in any case when the crop of beets falls below ten tons per acre.

GERMINATION OF THE SEED GROWN.

The sugar beet seed grown was examined during June and July in a Geneva apparatus as to its germinating power. The following data show the results of the examination: Two hundred seed pods were counted out in each

case on June 17 and left in the germinating apparatus as long as any seeds sprouted. The final counting was made on August 3.

Weight and germination of sugar beet seed.

	Weight of 200 seed pods.	Germination.
		Per cent.
Vilmorin II (high grade seed)	4.1325 gr.	159.0
Vilmorin I (ordinary seed)	4.2836 gr.	156.5
Kleinwanzleben	4.1771 gr.	58.5
Desprez Richest	4.7152 gr.	65.0
White Imperial	6.0987 gr.	139.0

For the sake of comparison we give below the results of the germination trials of 73 samples of sugar beet seed made during 1891 at the German experiment stations at Danzig and Breslau.*

	Weight of 200 pods.	Germination.
		Per cent.
Maximum	5.832 gr.	254.6
Minimum	3.046 gr.	105.0
Average	4.318 gr.	155.5

We notice that only two of the five varieties examined by us show a higher germination than the average of the German results, while two varieties came greatly below the minimum results found at the German stations.

YIELD OF BEETS.

The beets were harvested as in the previous years, by plowing a furrow close up to the rows and pulling the beets. They were then topped and hauled to the root cellar, each load being weighed and a basket full being taken out every time for determination of the quantity of dirt adhering to the beets. The quantities of beets harvested and other data in regard to the yield and quality of the beets are

*Landw. Jahrbucher, Erg. band I, 42.

given in the following table. The beets were analyzed at harvesting time, two different samples being taken; the average results are given in the table.

Yield and analysis of sugar beets, season 1892.

No. of rows.	VARIETY.	Beets from plat.	Tops from plat.	Per. Ct. dirt on beets.	Washed beets per acre.	Sugar in the juice.	Purity Coeffi-cient.	Av. wt. of beets.
	Plat I, subsoiled beets (7,605 sq. ft.).	Lbs.	Lbs.		Lbs.	Per cent.	Lbs.	Lbs.
13	Vilmorin I	1,044	401	8.15	16,470	13.10	79.2	.47
13	Kleinwanzleben.........	1,345	616	3.74	22,400	15.78	83.8	.64
13	Vilmorin II..............	1,332	608	7.15	21,240	16.52	83.5	.61
	Average		**543**		**20,040**	**15.13**	**82.2**	**.57**
	Not subsoiled beets (5,880 sq. ft.).							
13	Vilmorin I....	904	436	5.06	19,040	13.56	79.6	.55
13	Kleinwanzleben.........	978	432	6.32	20,360	16.86	85.7	.59
13	Vilmorin II	918	362	8.14	18,740	16.87	85.7	.54
	Average..		**410**		**19,380**	**15.76**	**83.7**	**.56**
	Plat II (14,535 sq. ft.).							
12	White Imperial	3,066		10.00	24,170	14.96	83.8	.75
13	Desprez Richest	3,372		12.70	25,710	16.44	87.9	.74
13	Vilmorin II	3,000		9.94	25,640	15.84	86.2	.68
	Average				**25,173**	**15.75**	**86.0**	**.72**

The total yield of washed beets from the plot was 14,505 lbs., which is at the rate of 22,620 lbs. per acre. The small yield must be attributed to the rather poor condition of the land and the shortness of the season. A number of beets that were transplanted July 11–13, grew only a little after that time.

It will be noticed that the sub-soiled beets yielded a little heavier, but contained .63 per cent. less of sugar in the juice. The increase in yield would amount to half a ton of beets per acre. If due allowance is made for the lower per cent. of sugar contained in the sub-soiled beets, the sub-soiling will still be found to have paid. The experi-

ment was conducted on a too small scale, however, to allow definite figures to be deducted.

The different varieties grown would rank as follows, when the average per cent. of sugar in the juice is considered: 1. Desprez Richest; 2. Vilmorin II (from high grade seed); 3. Kleinwanzleben; 4. White Imperial; 5. Vilmorin I.

Assuming that the beets contained 95 per cent. of juice, their average sugar content would be as follows: Vilmorin I, 12 66 per cent., Vilmorin II, 15.59 per cent., Kleinwanzleben 15.50 per cent., White Imperial 14.21 per cent., and Desprez Richest 15.62 per cent. On basis of these figures we estimate the yield of sugar per acre which the different varieties would have produced, viz.: Desprez Richest 4,0[illegible]6 lbs., White Imperial 3,435 lbs., Vilmorin II 3,410 lbs., Kleinwanzleben 3,313 lbs., and Vilmorin I 2,251 lbs. These figures are higher than those found during 1891 (see p. 295), but lower than those found in 1890. The average yield of sugar per acre for the three years mentioned would come at 3,821 lbs., or nearly 2 tons.

B. BEETS FROM FARMERS IN DIFFERENT PARTS OF THE STATE.

I. Season 1891.

One thousand pounds of Imported White Imperial sugar beet seed, bought of the Menominee Falls Sugar Company, was distributed in pound packages to 851 farmers during the spring of 1892; the farmers were requested to keep notes as to the growth and cultivation of the beets, and to forward samples of the beets grown to this Station in the fall for analysis. Owing to the drouth, the beets did not do well with a large number of farmers, and many paid but little attention to them as a consequence; in all 373 samples of beets were received and analyzed by the writer. Twenty samples were forwarded by mistake to the United States Department of Agriculture, Washington, D. C., and analyzed by their chemists. Of the farmers receiving sugar beet seed from us, 33 reported failure of crop and four wrote that they did not plant the seed. The samples analyzed were all from the White Imperial seed sent out,

except where otherwise stated. The 373 samples came from 59 counties in the state, making only nine counties that were not represented.

Most portions of the state suffered greatly from the drouth, although not all as much as the central part. The following table will give an idea of the distribution of rain during the summer months at 17 weather service stations in different parts of the state. The table is condensed from data furnished by Mr. W. L. Moore, Forecast Official, Milwaukee, Wis., to whom credit is due for the favor.

Rainfall for May to October inclusive, 1891, in inches.

Name of Station.	County.	May.	June	July.	Aug.	Sept.	Oct.	Total May-Oct.	Normal precipitation.
Prairie du Chien.	Crawford.....	1.65	2.95	1.76	2.32	1.73	1.82	12.23	....
Madison.........	Dane.........	1.42	3.68	2.64	1.41	.38	1.49	11.02	21.7
Eau Claire.......	Eau Claire....	2.00	5 40	2.20	1.70	1.07	3.10	15.47	....
Fond du Lac....	Fond du Lac.	.44	2.73	2.94	2.17	.58	1.63	10.47	....
Watertown......	Jefferson	1.88	......	2.25	1.47	.48	2.06	8.09*	....
Kenosha	Kenosha... .	1.52	4.27	3.67	1.62	.72	.....	11.80*	. ...
Lincoln..........	Kewaunee....	.83	3.12	1.85	3.62	1.42	......	10.84*	....
La Crosse..... ..	La Crosse	.69	5.62	2.92	1.48	1.77	1.87	14.35	23.1
Manitowoc......	Manitowoc...	.29	3.73	2.16	2 42	.76	1.70	11.06	19.7
Milwaukee.... ..	Milwaukee ...	1.47	4.98	3.57	2.83	.18	1.66	14.69	19.8
Appleton	Outagamie...	.01	5.20	5.20	1.45	.69	1.43	13.98	....
Janesville	Rock	.21	5.19	3.22	. ....	.18	2.35	11.15*	....
Hammond.......	St. Croix	1.19	7.61	2.73	2.20	1.48	1.98	17.19	....
Shawano	Shawano	.11	2.95	1.70	2.79	1.13	1.23	9.91	....
Medford.........	Taylor.... ...	.46	3.54	2.27	2 08	2.60	3.20	14.15	.. ..
Hillsborough....	Vernon	.70	3.47	2 99	1.36	1.04	2.03	11.59	... .
Centralia.......	Wood	.37	3.46	2 85	3.48	2.28	1.52	13.96	. . ..

* Total for four months.

The average results of the analyses of sugar beets made by the United States Department of Agriculture were as follows. The beets were forwarded during the first days of October, and must have been harvested between September

15 and 25. The detailed analyses were given in Bulletin 30 of this Station.

No. of samples.	No. of counties represented.	Av. wt. of beets oz.	Sugar in juice perct.	Sugar in beets perct.	Purity coefficient.
20	16	22¼	11.51	10.93	74.6

Only two samples contained above 15 per cent. of sugar in the juice, and only 9 out of 20 above 12 per cent. Doubtless the early date at which the beets were harvested will largely explain their inferior quality. No further data are on hand as regards soil, period of growth, or yield of beets from an acre of land.

We shall now give the average analyses of samples of sugar beets for each county, made at this Station during the fall of 1891. The single analyses with the names of the farmers forwarding the samples were published in Bulletin 30.

Sugar beets in Wisconsin, season 1891. *Average data for counties.*

COUNTY.	No. of Samples Analyzed.	Average Weight of Beets.	Estimated Yield per Acre.	Sugar in the Juice.	Purity Coefficient.	COUNTY.	No. of Samples Analyzed.	Average Weight of Beets.	Estimated Yield per Acre.	Sugar in the Juice.	Purity Coefficient.
		lbs.	lbs.	per ct.				lbs.	lbs.	per ct.	
Adams......	3	1.46	18,520	11.99	76.1	Marathon......	9	1.25	32,106	12.67	76.5
Barron.......	3	1.24	35,370	12.74	77.0	Marinette......	2	3.26	[illegible]	8.77	64.5
Brown........	4	2.30	35,888	10.75	74.9	Milwaukee	1	[illegible]	39,640	12.15	67.5
Buffalo.......	6	1.14	31,803	13.66	77.0	Monroe.	13	2.05	26,281	12.40	76.2
Calumet......	2	.77	20,040	13.01	77.7	Oconto	11	2.28	30,790	13.45	80.1
Chippewa...	8	2.99	15,320	11.06	73.2	Outagamie...	13	2.30	47,481	11.37	75.2
Clark.........	5	1.49	23,263	12.93	79.5	Ozaukee.......	3	2.14	41.327	13.30	77.7
Columbia.....	6	2.14	8,210	12.40	72.8	Pepin.........	4	1.94	21,616	14.06	77.4
Crawford.....	4	4.26	30,533	10.09	72.0	Polk..........	1	.93	... .	11.09	75.4
Dane.	12	1.75	28,805	13.77	77.5	Portage	7	1.58	25,055	11.56	74.3
Dodge	10	2.66	41,441	12.10	76.2	Racine.........	3	2.21	21,038	14.41	80.6
Door..	3	1.67	42,780	14.59	80.0	Richland	8	2.06	25,840	11.95	75.9
Dunn.......	9	2.41	25,766	12.19	77.1	Rock..........	16	1.76	22,783	12.82	76.4
Eau Claire....	9	1.66	27,980	12.12	77.4	St. Croix.. ...	7	1.19	39,711	12.29	74.4
Fond du Lac..	5	2.42	17,710	11.40	73.2	Sauk	3	1.74	47,621	14.11	77.8
Forest........	1	1.85	12,000	9.64	72.5	Sawyer... ...	1	2.88	52,200	10.69	73.8
Grant.........	5	2.46	26,400	11.62	71.5	Shawano	6	1.82	38,140	12.04	74.9
Green	2	1.43	37,670	14.30	80.3	Sheboygan	16	2.08	24.992	11.16	73.2
Green Lake...	1	2.55	.....	11.31	78.1	Taylor.........	13	1.54	17,505	12.81	78.2
Iowa.........	3	3.07	55,538	10.08	71.2	Trempealeau..	3	1.28	32,984	14.27	80.3
Jackson	1	4.12	....	7.79	65.6	Vernon...	11	1.96	25,511	12.19	75.6
Jefferson......	12	1.29	27,137	14.85	78.2	Walworth	9	2.45	38,729	12.55	76.1
Juneau.......	6	2.31	50,638	13.04	76.0	Washburn.....	1	.68	20,909	12.00	76.6
Kenosha	1	2.68	43,500	12.71	78.1	Washington....	10	1.67	26,700	14.35	75.7
Kewaunee....	12	2.25	26,240	12.49	74.0	Waukesha.....	13	2.29	26,607	12.74	75.6
La Crosse	9	2.17	30,401	12.88	76.3	Waupaca......	12	1.69	25,407	12.69	76.7
La Fayette...	4	1.86	52,708	12.27	77.0	Waushara.....	3	1.44	50,820	12.95	76.3
Langlade.....	1	1.60	48,120	12.91	81.4	Winnebago....	11	1.67	27,961	12.72	75.0
Lincoln.......	1	.68	16,355	14.90	83.5	Wood..... ...	6	2.34	37,353	12.60	77.8
Manitowoc ...	9	2.49	23,278	12.25	79.8	Average for 378 samples......	....	....	**30,750**	**12.56**	

The following extracts from the reports of the different farmers will give a good idea of the season and of the opinion of Wisconsin farmers of sugar beet culture. The numbers given correspond to those in the tables in bulletin No. 30:

3. "Seed did not come up for a month after planting, June 14.

13. This variety does not yield as well as No. 12, but seems to mature earlier.

14. Cut worms ravaged beets badly when they came up first.

16. No rain from April 25 to June 14, and none from July 1 to September 30, to wet the ground more than about an inch; in fact, it has been the driest season that the oldest settler has seen.

19. In the spring some insects or bugs hard on beets and rutabagas by side of them.

23–24. Only one row harvested, hence the excessive yield.

30. I think in a good growing season I could get as many again from the same ground.

35 and 64. The seeds lay in the ground for about four weeks before coming up.

54. Last crop grown on land wheat; the field was not manured for four years.

58. Harvested a great many beets that weighed 9 to 10 pounds.

62. Not more than two-thirds crop.

79. Cut worms destroyed fully one-half the plants.

80. Had the season been more favorable and they had received proper care and cultivation, the yield would have been three times as great.

81. The crop was nearly destroyed by cut worms.

85. This is not more than half a crop.

89. The like of the drouth has not been seen in this state since 1865.

90. No rain for about three months to wet the ground.

92. I rather plant potatoes and sell them at 25 cents a bushel and buy my sugar, than to raise sugar beets.

97. Time expended planting, cultivating and harvesting plot ($\frac{1}{24}$ th acre) 28½ hours for one man. (This would equal an expense of $4.56 per ton of beets, valuing 1 hour labor for 1 man 10 cents, and the yield of beets 15 tons per acre; see further under No. 247.)

100. Some of the beets were entirely stripped of leaves by a black bug.

101. The beets seem to stand drouth much better than other roots. Had turnips, carrots, etc., on same ground and they are worthless. My cows relished them and give a good flow of milk.

112. I think I could raise 40 tons per acre in a good season.

143. I think I can raise 1,200 bushels to the acre.

154. It was too dry for the seed to sprout until June 15, and then insects gnawed the plants off. The plot was only half covered with beets.

156. Had some beets of nine pounds, weight.

160. There is not more than half the yield there would be in an ordinary season.

162. Judging from the very bad season here for this kind of crop, I think they would be a very profitable crop to raise for any purpose that they can be used for.

167. Several beets weighed 9 to 10 pounds.

191. The seed did not germinate for nearly a month after planting, and then so unevenly that a careful transplanting could not produce an even stand.

193. Never had such weather in the last ten years.

199. Seed came up about June 25.

225 Beets are better than other roots for cows giving milk; they keep through the winter as good or better than potatoes.

235. Can be grown as well as potatoes, but like everything else the labor beats the balance sheet.

242. I have no doubt that beets can be profitably grown if the rows are put far enough apart so the greater part of the work can be done with a horse.

247. It required 22 hours and 35 minutes time for one man to plant, hoe, cultivate, thin, dig, top and put in the cellar; size of plot 4,620 sq. ft. (This would equal an expense of $1.42 per ton of beets, assuming cost of labor and yield as under No. 97.)

261. Obtained first premium at the county fair for the beets.

262. Beets were scarcely up by July 4, growth began about September 1, (!)

266. Not more than 10 per cent. of seed germinated on account of season being so dry.

295. Cut worms killed a good share of the beets.

302. There was one pound of tops to ten pounds of beets.

309. The season was unfavorable for most crops, nearly all summer being very dry. Corn did not do more than half.

311. I noticed a black bug, an inch long, from the middle of July to the last of August, which injured the leaves of the beets considerably. I have frequently noticed the same bug on potatoes. If you send me seed for next season I think I shall do considerably better, having learned some by experience.

317. During the hot weather in August, swarms of black bugs, one-half inch in length, went for the tops, in places making a clean sweep as far as they went, eating the tender part of the leaf, leaving nothing but the limb. The bugs remained about three weeks, the damage retarded the growth of the beets for a short time, but they recovered entirely from the injury and most of them are quite large now. . . . Am satisfied sugar beets would do well in this neighborhood. . . . My experience this year shows they are determined to grow in the soil here, no matter how long the drouth or how many bugs they have to contend with.

330. For growing beets, manure a year before planting to have manure well rotted.

342. The season being very dry the seed did not come up until June 25th. The seed being of good quality made a good stand. Had the season been favorable the yield could have been at least one-half more. Considering the very dry season I think sugar beets withstand the drouth better than the Yellow Tankard Mangle planted alongside of them, the beets being deeper rooted.

352. I think a common season ought to double the yield.

351. The season has been the driest that I ever experienced in Wisconsin. It is really wonderful that I got as good a crop as I have harvested.

353. The seed lay in the ground six weeks before germinating. With the same growing weather as in 1890 should have had twice the amount, for my land was far better than last year.

365. It has been an extremely dry season. Consider them almost a total failure."

DISCUSSION OF RESULTS OF ANALYSIS.

From the tables of analysis we deduct the following results:

Lowest analysis, 1891	7.12 per cent. sugar in the juice.
Highest	23.52 per cent. sugar in the juice.
Average of 373 analyses	12.56 per cent. sugar in the juice.
Average estimated yield of beets per acre	30,750 lbs.

The average per cent. of sugar in the juice may be considered a fair average, although there is evidently considerable room for improvement. The average for Germany during the season of 1890–91 was estimated at 12.5 per cent. The samples of beets analyzed at this station during 1890 (93 in all) averaged 12.46 per cent. of sugar in the juice. Only eleven farmers sent in beets both years; the averages of the samples furnished by these were: in 1890, 11.85 per cent.; in 1891, 14.30 per cent. of sugar in the juice, or 2.45 per cent higher in 1891. This would tend to show that the main reason for the rather inferior quality of beets grown by many farmers lies in their unacquaintance with the sugar beet and its culture; excepting the eleven farmers who furnished samples both years, there were only a very few who had had any previous experience in growing sugar beets. Another reason lies in the fact that the farmers

are apt to send in the largest beets grown, thinking that the larger beets they can grow the better; doubtless the results given in the above table are therefore in a large number of cases lower than truly representative samples would have shown.

II.—Season, 1892.

The sugar beet seed distributed to farmers of the state during the spring of 1892 was of the same varieties as were planted at the University farm, viz: Two kinds of Vilmorin improved sugar beet seed, Kleinwanzleben and Desprez Richest. Only sixty-two farmers sent in sugar beets for analysis in the fall; a good many reported failures of the crop through flooding of the fields during the excessive rains of May and June, and others did not plant at all, as their ordinary crops took up all their time and available land when planting time at last came.

The following meteorological data for the season for several points in the state were furnished us through the kindness of Mr. W. L. Moore, Forecast Official, Milwaukee, Wis.

Precipitation for May to October, incl., 1892, *in inches.*

Name of Station.	County.	May.	June.	July.	August.	September.	October.	Total May-Oct.	Normal precipitation May-Oct.
Pra. du Chien	Crawford.....	8.26	13.53	2.82	3.37	1.96	1.26	31.20	22.3
Eau Claire....	Eau Claire...	6.15	9.10	*6.97	*1.97	2.90	1.70	28.79	....
Fond du Lac.	Fond du Lac..	6.86	8.31	4.56	1.59	2.46	1.03	24.81	19.8
Watertown...	Jefferson. ...	5.95	8.76	1.21	2.26	3.85	.52	22.55	....
Lincoln.......	Kewaunee....	*5.42	4.62	3.20	2.22	1.19	1.10	17.76	....
La Crosse.....	La Crosse.....	7.06	8.21	3.97	1.88	3.07	2.47	26.66	23.1
Manitowoc. ..	Manitowoc. .	5.65	7.21	3.03	4.30	1.74	1.33	23.26	19.7
Milwaukee....	Milwaukee....	8.12	6.33	1.20	3.47	2.21	1.66	22.99	19.1
Shawano......	Shawano.	5.83	5.82	2.30	2.44	1.16	2.42	19.97	....
Centralia.....	Wood.........	4.57	6.60	3.58	2.38	1.65	1.56	20.34	....

* Approximate data.

By comparing the figures in this table with those on page 301 it will be seen how radically different the seasons of 1891

and 1892 were. The months of May and June, 1892, were extremely wet and cold; planting was as a rule not done until May 15, and the growing season was therefore shorter than usual. Of the two years, 1892 must be considered the more favorable one to sugar beet culture, as to crops generally. The examination of the beets sent in for analysis gave results as shown in the tables in the appendix. The average data for the different counties represented are given in the following table:

Sugar beets in Wisconsin, 1892.

Arranged by Counties.

County.	No. of samples.	Av. weight of Beets.	Estimate yield per acre.	Sugar in Juice.	Purity Coefficient.	County.	No. of samples.	Av. weight of Beets.	Estimated yield per acre.	Sugar in Juice.	Purity Coefficient.
		Lbs	Lbs.	Per ct.				Lbs	Lbs.	Per ct.	
Buffalo........	2	1.22	....	14.55	81.9	Monroe	3	2.22	20.313	11.95	76.5
Calumet.......	2	1.58	33.975	18.03	82.1	Oconto	1	.70	8.116	16.77	87.6
Chippewa.....	5	1.47	38.443	15.88	84.2	Ozaukee.......	1	2.28	....	14.84	83.4
Clark....	2	.95	19.455	17.19	86.2	Pepin.	1	4.08	27.880	17.31	85.8
Columbia....	4	2.27	47.913	12.81	77.7	Portage........	1	1.90	....	15.26	81.1
Dunn...	2	.64	14.812	15.33	88.0	Shawano	1	1.09	26.660	15.50	84.6
Fond du Lac...	3	1.48	27.879	14.49	77.9	Sheboygan. ...	6	1.65	45.106	14.85	77.1
Grant.........	1	1.85	....	10.55	76.9	Taylor.........	2	1.21	... ...	18.85	83.1
Green..........	4	1.01	28.650	12.12	76.1	Walworth. ...	1	1.03	.... ..	16.96	88.7
Jefferson......	4	1.45	40.066	18.52	80.9	Washington....	2	1.46	39.790	14.16	81.4
Kewaunee.....	4	3.41	81.531	15.12	80.5	Winnebago....	2	1.25	34 845	16.26	87.2
Lincoln........	2	.62	31.070	18.69	87.1	Wood..........	1	.83	14.157	17.16	89.1
Manitowoc	4	1.36	42.425	15.13	84.4	Average for 62 samples.. ...	....	..	38.545	14.34	....

The average percentage of sugar in the juice of the beets sent for analysis during 1892 came at 14.34 per cent., and the average yield per acre of beets at 38,545 lbs. This is a great improvement over last year's results both as regards the quality and the quantity of the beets (see p. 303). Doubtless the quality of the seed sent out during 1892 was better than that sent out during the spring of 1891, but it is not at all likely that the better results are due entirely to this cause; the more favorable season and the greater skill of

the farmers in growing sugar beets are doubtless also important factors. Twenty-five farmers sent in beets for analysis both years; the average of 28 samples for these during 1891 was 12.57 per cent., and of 42 samples during 1892 was 14.58 per cent., or an improvement of 2 per cent. in the sugar content of the juice. The following figures will show the improvement in the beets sent for analysis to this Station during the last three years:

Average per cent. of sugar in juice, 1890, (93 analyses)...................	12.46 per cent.
Average per cent. of sugar in juice, 1891, (373 analyses)	12.56 per cent.
Average per cent. of sugar in juice, 1892, (62 analyses)	14.34 per cent.

SUGAR CONTENT OF DIFFERENT VARIETIES OF BEETS.

The different varieties received for analyses during 1892 had the following average weight, yield per acre, sugar content and purity coefficients.

	No. of analyses.	Av. Wt. of beets	Yield per acre.	Sugar in juice	Purity co-efficient.	Calculated sugar in beets.	Calculated sugar per acre.
		Lbs.	Lbs.	Per cent.		Per cent.	Lbs.
Vilmorin I	13	1.94	45.927	13.27	78.3	12.61	5792
Vilmorin II (high grade seed)	14	1.26	25.400	15.92	83 9	15.12	3840
Kleinwanzleben.........	14	1.57	33.400	14.69	80.2	13.96	4662
Desprez Richest	16	1.48	36.949	15.69	81.4	14.91	5509

The high grade Vilmorin had the richest juice, next came Desprez Richest, then Kleinwanzleben and last of all Vilmorin I. The Vilmorin I would yield the largest quantity of sugar per acre, however; and the other varieties would follow in this order: Desprez Richest, Kleinwanzleben and high grade Vilmorin.

The following table gives the average results of the sugar beet culture in Wisconsin for 1891 and 1892, arranged according to counties. 435 analyses are included in the table in all, and as the two seasons of 1891 and 1892 were very different as regards climatic conditions, it is believed that the results represent fairly well the acreage and quality of beets which farmers in Wisconsin can raise without having had much previous experience in sugar beet culture.

Sugar Beets in Wisconsin, Seasons 1891–2.

Average Data for Counties.

County.	No. of Samples Analyzed.	Average Weight of Beets.	Estimated Yield per Acre.	Sugar in Juice.	Purity Coefficient.	County.	No. of Samples Analyzed.	Average Weight of Beets.	Estimated Yield per Acre.	Sugar in Juice.	Purity Coefficient.
		Lbs	Lbs.	Per ct.				Lbs	Lbs.	Per ct.	
Adams........	3	1.46	18,550	11.99	76.1	Marathon.....	9	1.25	32,106	12.67	76.5
Barron	3	1.24	33,370	12.74	77.0	Marinette.....	2	3.26	57,064	8.77	64.5
Brown...... ..	4	2.30	35,883	10.75	74.9	Milwaukee....	1	1.29	39,640	12.15	67.5
Buffalo	8	1.16	31,803	13.88	78.2	Monroe.......	16	2.08	20,960	12.31	76.3
Calumet.......	4	1.17	21,997	14.02	79.9	Oconto	12	2.15	27,011	13.73	80.7
Chippewa.	13	2.41	26,886	12.72	77.4	Outagamie ...	13	2.30	47,481	11.37	75.2
Clark	7	1.34	17,849	11.76	69.1	Ozaukee	4	2.17	41,327	13.68	79.1
Columbia	10	2.19	24,109	12.50	74.8	Pepin.........	5	2.37	23,704	14.71	77.1
Crawford.... .	4	4.26	30,533	10.09	72.0	Polk..........	1	.93	....	11.09	75.4
Dane	12	1.75	28,805	13.77	77.5	Portage.......	8	1.58	25,055	12.02	75.1
Dodge	10	2.66	41,441	12.10	76.2	Racine	3	2.21	21,038	14.41	80.6
Door...	3	1.67	42,780	14.59	80.0	Richland......	8	2.06	25,840	11.95	75.9
Dunn..........	11	2.09	25,277	12.75	69.9	Rock.........	16	1.76	22,783	12.82	76.4
Eau Claire.....	9	1.66	27,990	12.12	77.4	St. Croix......	7	1.19	39,711	12.29	74.4
Fond du Lac..	8	2.07	19,568	12.56	75.0	Sauk.....	3	1.74	47,521	14.11	77.8
Forest..	1	1.85	12,000	9.64	72.5	Sawyer.... .	1	2.88	52,200	10.69	73.8
Grant..........	6	2.36	26,400	13.73	86.9	Shawano	8	1.64	31,316	10.97	66.7
Green..........	6	1.32	30,905	12.83	77.5	Sheboygan ...	22	1.96	32,728	12.17	69.9
Green Lake. .	1	2.55	....	11.31	78.1	Taylor........	15	1.49	15,317	13.61	78.2
Iowa	3	3.07	55,538	10.08	71.2	Trempealeau..	3	1.23	32,984	14.27	80.3
Jackson.	1	4.12	... ...	7.79	65.6	Vernon... ...	11	1.96	25,511	12.19	75.6
Jefferson..... .	16	1.33	39,480	14.51	78.9	Walworth ...	10	2.31	38,729	12.99	77.4
Juneau.......	6	2.31	50,638	13.04	76.0	Washburn	1	.68	20,909	12.09	76.6
Kenosha.... ..	1	2.68	43,500	12.71	78.1	Washington...	12	1.68	30,440	13.73	80.7
Kewaunee	16	2.54	70,474	13.15	79.6	Waukesha. ...	13	2.29	26,607	12.74	75.6
La Crosse.....	9	2.17	30,401	12.88	76.3	Waupaca.. ...	12	1.69	25,407	12.69	76.7
La Fayette . ..	4	1.86	52,708	12.27	77.0	Waushara. ...	3	1.41	50,820	12.95	76.3
Langlade	1	1.60	48,120	12.91	81.4	Winnebago ...	13	1.67	29,213	13.63	76.8
Lincoln..	3	.63	36,753	10.53	56.2	Wood.........	7	2.12	29,304	13.25	79.1
Manitowoc	13	2.14	34,064	13.14	80.8	Average of 435 analyses.....	....	....	*32,122*	*12.81*	..

Twenty-five out of the fifty nine counties represented have an average sugar content of the juice above the mean for the state; nineteen counties have an average above thirteen per cent. and seven above fourteen per cent., viz: Calumet (4 samples), Door (3), Jefferson (16), Pepin (5), Racine (3), Sauk (3), Trempealeau (3). Of these Pepin and Jefferson have the highest averages, viz: 14.51 and 14.71 per cent, respectively. The counties mentioned do not belong to any particular section of the state, but lie in the western, southern and northeastern portion of the state. This would indicate that successful sugar beet culture with us is more a question of skill in growing than one of soil. In almost any part of the state, soil well adapted to sugar beet culture may be found; what is needed is farmers who understand the cultivation of the beets, and enough of them within a limited area to furnish a sufficient quantity of beets to supply a sugar beet factory with 200 to 300 tons of beets daily for a campaign of about three months. This means the product from not less than 1,500 acres of land in an average year.

SUMMARY.

I. *Season 1891.*

1. The eleven varieties of sugar beets grown at the University farm during the season of 1891, contained from 14.99 to 20.53 per cent. sugar in the juice; the average yield of washed beets per acre was 14,677 pounds. On account of the severe drouth the crop was less than one-half; the per cent. of sugar in the beets was somewhat increased from the same reason.

2. Of the 373 samples of beets received from farmers in different parts of the state, 175 samples contained above 13 per cent sugar in the juice, the richest beets containing 23.52 per cent. and the poorest 7.12 per cent.

The average of all analyses was 12.56 per cent. sugar in the juice. The average estimated yield of beets per acre was about fifteen tons.

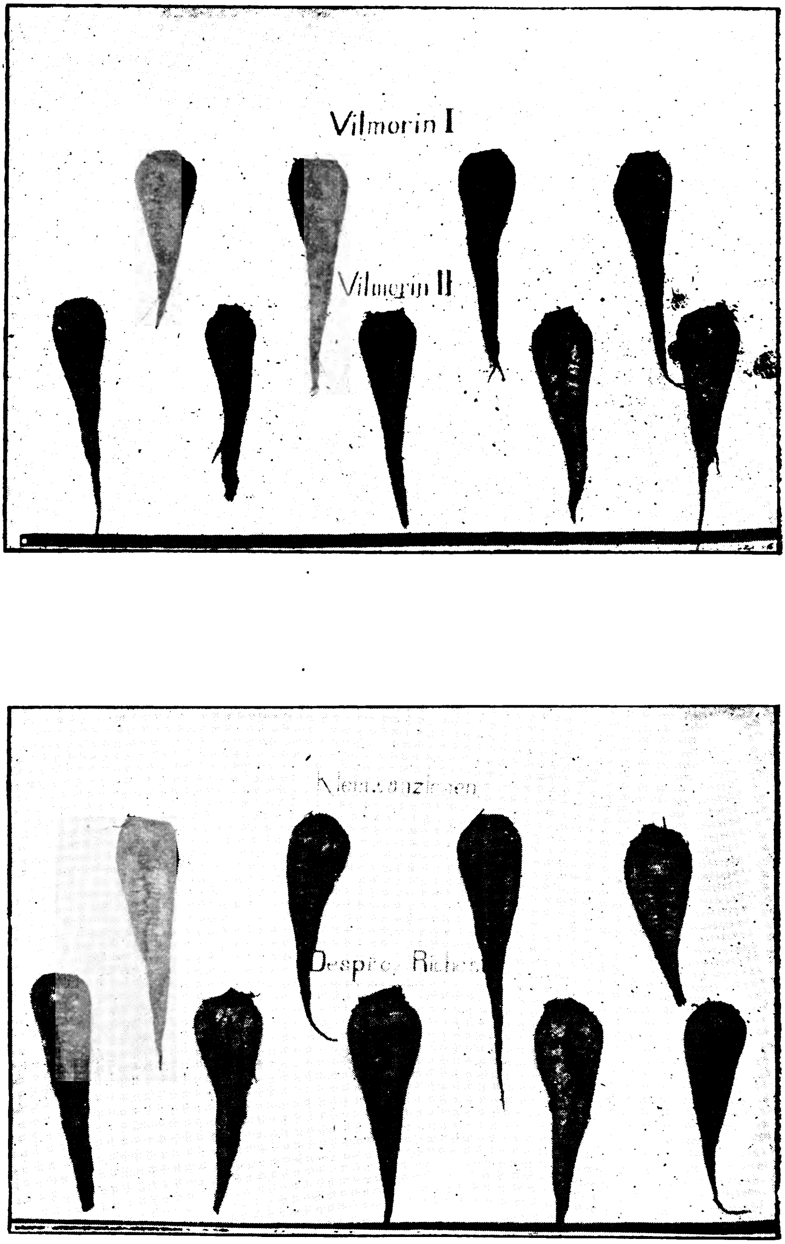

FIG. 72.—Specimens of sugar beets.

II. *Season 1892.*

1. The five varieties of sugar beets grown at the University farm during 1892 contained from 13.33 per cent to 16.44 per cent. of sugar in the juice; the average yield of washed beets per acre was 22,620 lbs.

2. Of the 62 samples of beets received from farmers in different parts of the state, 49 samples contained above 13 per cent. sugar in the juice, the richest beets containing 19.71 per cent. and the poorest 7.93 per. cent. Average sugar content in the juice for all samples, 14.34 per cent.; average yield per acre, 38,545 lbs.

The average sugar content for 435 samples of beets grown by Wisconsin farmers during 1891 and 1892 was 12.81 per cent. and the average yield of beets 32,122 lbs.

IN CONCLUSION.

The farmers of Wisconsin are urged to continue their interest in the important question of local sugar production. From our lands now in cultivation we could well spare all the acres needed to produce not only the sugar sufficient for home consumption, but for a population many times larger than our own.

Before we can conscientiously ask any one to invest a dollar to the construction of factories, however, there should be some real assurance that our people are ready and willing to grow beets in sufficient quantity and proper quality to keep a factory well supplied with suitable beets for a long working season. The sugar beet plant must be grown on proper soil with the proper cultivation, and to give it these requires judgment, study and experience. When we have progressed this far, there is no fear that capital will longer delay the construction of proper factories to turn the beets into sugar. Sugar is an agricultural product as much as beef or butter, and our investigations show that Wisconsin is in the beet sugar belt. Let there be a continued, united effort until the sugar industry is firmly established within our borders.

COMPOSITION OF FEEDING STUFFS.

F. W. WOLL.

When the agricultural chemist speaks of the feeding stuffs used for the nutrition of farm animals, he employs certain technical terms, which, to the reader familiar with them, at once convey a full understanding of the fodder as far as its chemical composition is concerned; to those unfamiliar with these terms, on the other hand, they are wholly unintelligible. In the following, some brief explanations on this point will be given, in order to enable the reader to understand the discussions entered upon at other places in this report and elsewhere, concerning the chemical composition of feeding stuffs.

The fodders are made up of I, *Water*, and II, *Dry Matter*.

I. *Water* is found in all feeding stuffs. It is present in by far the larger proportion in green and succulent fodders; out of 100 lbs. of pasture grass, 80 lbs. are water; green clover and silage contain about the same quantity of water, while mangolds and turnips contain as much as 90 lbs. out of every hundred pounds of fodder. In the different kinds of hay, straw and grain, the quantity of water present is only from 10 to 15 per cent. *Water* (*moisture*) is determined by heating the fodder prepared for analysis for several hours at 212° F.

II. *Dry matter* is what is left behind when all water is driven off the fodder. It is composed of (1) *Mineral matter* or *ash*, this being the non-combustible part of the plant, and (2) *Organic matter*. The *ash* goes to make the bones of the animal or to supply material for maintenance of other parts of the animal body. *The organic matter*, being the part of the fodder which is destroyed by combustion, is composed of the following groups of nutritive components,

(a) *fat*, (b) *crude protein*, (c) *crude fiber*, and (d) *nitrogen-free extract.*

a. *Fat or Ether extract*, includes what is dissolved out with dry ether from the water-free substance. Fat forms the main part of the extract; the other matters extracted are chlorophyll (the green coloring matter in plants), plant wax, resins, and various other substances; the term *ether extract* is used by the writer, as it gives a truer name for the group than does *fat.*

b. *Crude protein* signifies a large number of bodies characterized by the fact that they all contain the element nitrogen, which none of the other components of organic matter contain. Crude protein includes *albuminoids* and *amides.* The *albuminoids* are the substances which go to make up the flesh, ligaments, tendons, etc., of the animal body; hence they are often called *flesh-formers.* White of egg, lean meat, curd of milk and gluten are typical albuminoids. The albuminoids are either insoluble in water or, if soluble, are rendered insoluble by heat, acids or ferments. In this they differ from the other group of nitrogenous organic bodies, the *amides.* These are all soluble in water. Asparagin and glutamin are the amides present in plants in the largest quantities. The nutritive value of amides is probably somewhat lower than that of the albuminoids, as they cannot fill all their functions. Their value has not yet, however, been fully ascertained, the study of this subject having only been taken up in later years. Amides are present in considerable quantities in immature plants, root crops and silage. They are only in a transitory state in the living plant, being later converted into albuminoids and serving as agents for the transfer of protein from one part of the plant to another.

The albuminoids contain on an average about 16 per cent. of nitrogen. In the chemical analyses, total nitrogen and albuminoid nitrogen are determined; the total nitrogen multiplied by 6.25 ($=\frac{100}{16}$) equals crude protein, and albuminoid nitrogen multiplied by 6.25 equals albuminoids; the difference gives the amides.

The protein bodies are of the greatest importance for the nutrition of animals. They supply the material for building up the tissues of the body, and for maintaining these under the wear caused by the vital functions. If present in excess, they may be used for formation of fat in the animal body, or for production of heat. This, however, is not rational feeding, as the nitrogen-free nutritive elements as starch, sugar, cellulose, will do the same work, and they may be procured at less expense.

c. *Crude fiber* or *crude cellulose* is the framework of the plants, forming the walls of their cells. It is usually the least digestible part of the plants. It is determined in the laboratory by boiling the fodder successively with a weak acid and alkali, thus dissolving out all other parts of the fodder.

d. *Nitrogen-free extract* signifies what is left of the organic matter of the plant after deducting the preceding groups of elements. It contains *starch, sugar, pentosans, gums, organic acids* and other bodies. Together with cellulose, it forms the group of bodies called *carbohydrates.* They all contain the three elements, carbon, oxygen and hydrogen. A general name for carbhydrates is *heat producers*; their office in animal nutrition, besides producing heat, is to assist in the formation of fat and to supply energy for the production of work. Nitrogen-free extract is determined by difference; total dry matter minus ash, ether extract, crude protein and crude fiber giving the percentage present.

The following table gives the chemical composition of our common feeding stuffs. The figures are averages of a number of analyses of each feed. The larger the number of analyses, the nearer the data will naturally come to true averages. It is to be remembered, however, that, especially in the case of the coarse fodders, the chemical composition changes considerably with the maturity of the plant, the soil, the treatment of the soil, and the treatment which the fodder has received from the time of cultivation to when it is fed to the animals. The composition of a certain

feeding stuff may therefore differ considerably from the average analysis. The right way to do would be to give the variations in composition found, and leave it to the judgment of those using the table to determine what figures to choose in their particular case. As this, however, requires an intimate knowledge of the relations between soil and plants, that only few are in possession of, it is not thought advisable to do so, and only average figures are therefore given.

The quantities of the digestible portion of each fodder, as determined by numerous digestion experiments abroad as well as in this country, are also given in the table. The figures giving the composition of the fodders are in most cases the averages taken from the compilation of analyses of American fodders by *Dr. E. H. Jenkins* and *A. L. Winton, Jr.**

The composition of the fodders starred is taken from Koenig and Dietrich's computation of German analyses. The percentages of digestible matter are calculated from the digestible coefficients given in the Connecticut Station Report for 1886; or from later data where such were at hand. The colored chart opposite page 320, showing the composition of feeding stuffs, has been prepared from the figures in the table. It is believed that it will be of service to the farmer who is studying his business; the colors will give a better idea of the components of our ordinary cattle foods than figures alone can.

*Experiment Station Bulletin No. 11, Office of Experiment Stations, Washington, D. C., 1892.

TABLE I.—*Average Composition of American Feeding Stuffs.*

FEEDING STUFFS.	No. of analyses.	PERCENTAGE COMPOSITION. Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.	PER CENT. DIGESTIBLE MATTER. Crude protein.	Carbohydrates.	Ether extract.
Green fodders and silage.											
Pasture grass	....	80.0	2.0	3.5	4.0	9.7	.8	18 0	2.6	10.6	.5
Green fodder corn (maize)	126	79.3	1.2	1.8	5.0	12.2	.5	19.5	1.3	11.8	.4
Alfalfa (lucern)	23	71.8	2.7	4.8	7.4	12.3	1.0	25.5	3.6	11.4	.4
Green clover	43	70.8	2.1	4.4	8.1	13.5	1.1	27.1	2.9	14.1	.7
Alsike clover, in bloom	4	74.8	2.0	3.9	7.4	11.0	.9	23.2	2.7	13.1	.6
Rye fodder	7	76.6	1.8	2.6	11.6	6.8	.6	21.6	2.1	14.1	.4
Oat fodder	5	62.2	2.5	3.4	11.2	19.3	1.4	35.3	2.7	22.7	1.0
Sorghum fodder	11	79.4	1.1	1.3	6 1	11.6	.5	19.5	.8	12.7	.4
Red top, in bloom	5	64.8	2.3	3.3	9.4	19.1	1.2	32.9	2.3	20.5	.7
Meadow fescue, in bloom	4	69.9	1.8	2.4	10.8	14.3	.8	28.3	1.7	17.8	.5
Timothy	56	61.6	2.1	3.1	11.8	20.2	1.2	36.3	2.2	23.0	.7
Blue grass	18	65.1	2 8	4.1	9.1	17.6	1.3	32.1	2.9	19.2	.8
Corn silage	99	79.1	1.4	1.7	6.0	11.1	.8	19.5	1 2	11.8	.6
Corn silage, Wisconsin analyses	17	73.6	2.1	2.7	7.8	12 9	.9	24.2	1.1	13.2	.7
Clover silage	5	72.0	2.6	4.2	8.4	11.6	1.2	25.4	2.2	10.0	.5
Sorghum silage	6	76.1	1.1	.8	6.4	15.3	.3	22.8	.4	14.0	.2
Hay and dry coarse fodders.											
Fodder corn (maize), field cured	35	42.2	2.7	4.5	14.3	34.7	1.6	55.1	1.8	32.0	1.2
Same, Wisconsin analyses	5	29.0	4.2	6.5	22.1	36.5	1.7	66.8	2.6	38.4	1.3
Corn stalks (stover), field cured	60	40.1	3.4	3.8	19.7	31.9	1.1	56.5	2.0	34.1	.6
Hay from red clover	38	15.3	6.2	12.3	24.8	38.1	3.3	78.5	6.5	34.9	1.6
Hay from mammoth clover	10	21.2	6.1	10.7	24.5	33.6	3.9	72.7	5.7	32.0	1.9
Hay from alfalfa (lucern)	21	8.4	7.4	14.3	25.0	42.7	2 2	84.2	7.6	37.8	1.3
Hay from alsike clover	9	9.7	8.3	12 8	25.6	40.7	2.9	82.0	6.8	36.8	1.4
Oat hay	6	8.9	6.2	7.6	29.3	45.1	2.9	84.9	4.3	46.4	1.5
Hay from mixed meadow grasses	11	16.0	4.6	6.4	29.9	41.0	2.1	79.4	3.6	42.7	1.0
Hay from Hungarian grass	12	7.7	6.0	7.5	27.7	49.0	2.1	86.3	4.5	46.4	1.0
Timothy hay	68	13.2	4.4	5.9	29.0	45.0	2.5	82 4	3.0	43.9	1.2

Average Composition of American Feeding Stuffs.

FEEDING STUFFS.	No. of Analyses.	PERCENTAGE COMPOSITION.							PER CENT. DIGESTIBLE MATTER.		
		Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Organic matter.	Crude portein.	Carbo-hydrates.	Ether extract.
Oat Straw	12	9.2	5.1	4.0	37.0	42.4	2.3	85.7	1.6	41.4	.7
Barley straw*	97	14.2	5.7	3.5	36 0	39.0	1.5	80.1	.9	41.3	.6
Wheat straw	7	9.6	4.2	3.4	38.1	43.4	1.3	86.2	.8	37.9	.5
Rye straw	7	7.1	3.2	3.0	38.9	46.6	1.2	89.7	.8	42.7	.4
Buckwheat straw	3	9 9	5.5	5.2	43.0	35.1	1.3	84.6	2.3	37.7	.6
Roots and Tubers.											
Potatoes	12	78.9	1.0	2.1	.6	17.3	.1	20.1	1.4	16.1	.1
Sweet potatoes	6	71.1	1.0	1.5	1.3	24.7	.4	27.9	.9	22 2	.3
Red beets	9	88.5	1.0	1.5	.9	8.0	.1	10.5	.9	7.6	.1
Sugar beets	19	86.5	.9	1.8	.9	9.8	.1	12.6	1.1	9.3	.1
Mangel-wurzels	9	90.9	1.1	1 4	.9	5.5	.2	8.0	1.1	4.8	.2
Rutabagas	4	88.6	1.2	1.2	1.3	7.5	.2	10.2	.9	7.1	.2
Turnips	3	90 5	.8	1.1	1 2	6.2	.2	8.7	.6	5.5	.2
Carrots	8	88.6	1.0	1.1	1.3	7.6	.4	10.4	1.0	7.1	.3
Grains and Mill Products.											
Corn (maize)	208	10.9	1.5	10.5	2.1	69.6	5 4	87.6	7.1	62.7	4.2
Corn and cob meal	7	15.1	1.5	8.5	6.6	64.8	3.5	83 4	6.5	56.3	2.9
Corn cob	18	10.7	1.4	2.4	30.1	54.9	.5	87.9	1.6	43.9	.3
Corn bran	2	10.9	1.7	9.4	4.8	67.3	5.9	87.4	6.2	50.9	3.4
Oats	30	11.0	3.0	11 8	9.5	59.7	5.0	86.0	9.1	44.7	4.1
Oat shorts*	6	10 0	5.2	16.2	7.5	54.5	6.6	84.8	12.6	45.7	5.4
Oat feed	4	7.7	3.7	16.0	6.1	59.4	7.1	88.6	12.5	46.9	2.8
Oat dust	2	6.5	6.9	13.5	18.2	50.2	4.8	86.6	8.9	38.4	5.1
Barley	10	10.9	2.4	12.4	2.7	69.8	1.8	86.7	9.5	66.1	1.2
Barley screenings	2	12.2	3.6	12.3	7.3	61.8	2.8	84.2	9.3	57.3	1.8
Wheat	310	10.5	1.8	11.9	1.8	71.9	2.1	87.7	9.2	64.9	1.4
Wheat bran—roller process	7	12.0	5.6	16.1	8.4	53.7	4.2	82.4	12.6	44.1	2.9
Wheat bran—old process	9	12.0	4.9	13.0	8.1	58.2	3.8	83.1	10.1	47.5	2.6
Wheat shorts	12	11.8	4.6	14.9	7.4	56.8	4.5	83.6	11.6	45.4	3.2
Wheat middlings	33	12.1	3.4	15.7	4.7	60.2	4.0	84.5	12.2	47.2	2.9

Average Composition of American Feeding Stuffs.

Feeding Stuffs.	No. of Analyses.	Percentage Composition. Water.	Ash.	Crude Protein.	Crude Fibre.	Nitrogen-free Extract.	Ether Extract.	Organic Matter	Per Cent Digestible Matter. Crude Protein.	Carbohydrates.	Ether Extract.
Rye	6	11.6	1.9	10.6	1.7	72.5	1.7	86.5	8.3	65.5	1.2
Rye bran	7	11.6	3.6	14.7	3.5	63.8	2.8	84.8	9.7	48.0	1.6
Rye shorts	1	9.3	4.9	18.0	5.1	59.9	2.8	85.8	11.9	45.1	1.6
Buckwheat	8	12.6	2.0	10.0	8.7	64.5	2.2	85.4	7.7	49.2	1.8
Buckwheat bran	2	10.5	3.0	12.4	31.9	38.8	3.3	86.5	7.4	30.4	1.9
Buckwheat shorts	2	11.1	5.1	27.1	8.3	40.8	7.6	83.8	21.1	33.5	5.5
Buckwheat middlings	6	12.7	5.1	28.2	4.2	42.3	7.5	82 2	22.0	33.4	5.4
Rice	10	12.4	.4	7.4	.2	79.2	.4	87.2	4.8	72.2	.3
Rice bran	5	9.7	10.0	12.1	9.5	49.9	8.8	80.3	5.3	45.1	7.3
Rice hulls	3	8.2	13.2	3.6	35.7	38.6	.7	78.6	1.6	44.5	.6
Rice polish	4	10.0	6.7	11.7	6.3	58.0	7.3	83.3	9.0	56.4	6.5
Pea meal	2	10.5	2.6	20.2	14.4	51.1	1.2	86.9	18.0	56.0	.9
Sorghum seed	10	12.8	2.1	9.1	2.6	69.8	3.6	85.1	7.0	52.1	3.1
Cow pea	5	14.8	3.2	20.8	4.1	55.7	1.4	82.0	18.3	54.2	1.1
Soja bean	8	10.8	4.7	34.0	4.8	28.8	16.9	84 5	29 6	17.9	15.9
Miscellaneous Feeds.											
Malt sprouts	5	9.6	5.9	24.8	11.0	47.0	1.7	84 5	19.8	36.2	1.7
Brewers' grains	15	75.7	1.0	5.4	3.8	12.5	1.6	23 3	3.9	9.5	1.3
Brewers' grains, dried	5	7.7	3.6	22.2	12.3	47.9	6.3	88.7	16.2	35.5	5.3
Hominy chops	12	11.1	2.5	9.8	3.8	64.5	8.3	86.4	8.9	61.9	6.3
Corn germ	8	10.7	4.0	9.8	4.1	64.0	7.4	85.3	8.9	61.4	5.6
Germ meal	3	8.6	1.0	10.9	10.2	64.0	5.4	90.4	9.3	63.6	4.1
Gluten meal	32	9.6	.7	29.4	1.6	52.4	7.4	89.7	25.0	49.4	5.6
Starch feed, wet	12	65 4	.3	6.1	3.1	22.0	3.1	34.3	5.5	21.7	2.3
Cotton seed meal	37	8.2	7.2	42.4	5.6	23.8	12 9	84.6	36.9	18.1	12.3
Cotton seed hulls	10	9.9	2.9	4.2	47.4	33.2	2.2	87.2	1.0	26.2	1.8
Linseed meal	21	9.2	5.7	32.9	8.9	35.4	7.9	85.1	27.0	32.2	7.1
Palm nut meal*	600	10.4	4.3	16.8	24.0	35.0	9.5	85.3	16.0	52.6	9.0
Apple pomace	7	76.7	.5	1.4	3.9	16.2	1.3	22.8	1.0	11.9	1.1
Dried blood*	3	8.5	4.7	84.4	...	......	2.5	86.8	59.1	....	2.3
Skimmed milk*	96	90.4	.7	3.3	....	4.7	.8	8.9	3.1	4.7	.8
Butter milk*	85	90.1	.7	4.0	....	4.0	1.1	9.2	3.9	4.0	1.1
Whey*	46	93.4	.7	.9	....	4.8	.3	5.9	.8	4.7	.3

y*.........	46	93.4	.7	.9	....	4.8	.3	5.9	.8	4.7	.3

Scientists have been working for more than a generation to solve the problem of the systematic feeding of farm animals. It was soon discovered that the nitrogenous bodies played an important part in the nutrition of animals, a ration containing a large proportion of these bodies giving the best results, other things being equal. As the outcome of the experience gained by long continued, patient investigations, certain feeding standards were constructed, giving quantities of total dry matter, of digestible matter, and the proportion of the different nutrients in the latter. This work has been done almost exclusively by German experimenters, and to these belong the honor of having first brought forward to the light the principles underlying the nutrition of farm animals.

Below are given feeding standards for farm animals according to the German scientist, Dr. Emil Wolff. In publishing these standard rations here we do not offer them to our farmers as safe guides in all cases, under the conditions present on this continent. Very likely American feeding experience will, in time, show the rations given to be incorrect in many instances with our climate and foods; we have seen that our best dairymen do not follow the standard ration for milch cows in their systems of feeding (p. 84); the ration for the maintenance of steers in the same way was long ago proved faulty with us by *Caldwell and †Sanborn.

Nevertheless the rations may be of some service to us in a general way; they are published here, for the additional reasons that references are often made to them in our agricultural literature, and they are the first systematic comprehensive schedule of the general requirements of ordinary farm animals.

The *nutritive ratio* is the proportion of digestible protein to digestible carbohydrates and fat in a ration, the percentage of fat being multiplied by 2.2 and added to the carbohydrates, as one pound of fat will produce about 2.2

*New Hampshire Agriculture, Vol. XI (1881), 90–92.

†Report Cornell University Experiment Station, 1882–3, 18–22.

times as much heat when burnt as fuel, as does one pound of carbohydrates.

Table II. Feeding Standards.—According to Wolff.

(Per day and per 1,000 lbs. live weight.)

	Total organic substance.	Nutritive (digestible) substances. Crude protein.	Carbohydrates.	Ether extract.	Total nutritive substances.	Nutritive ratio.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
1. Steers at rest in stall	17.5	0.7	8.0	0.15	8.85	1:12.0
2. Wool sheep, coarser breeds	20.0	1.2	10.3	0.20	11.70	1:9.0
Wool sheep, finer breeds	22.5	1.5	11.4	0.25	13.15	1:8.0
3. Steers moderately worked	24.0	1.6	11.3	0.30	13.20	1:7.5
Steers heavily worked	26.0	2.4	13.2	0.50	16.10	1:6.0
4. Horses moderately worked	21.0	1.6	10.0	0.50	12.10	1:7.0
Horses heavily worked	23.0	2.5	12.1	0.70	15.30	1:5.5
5. Milch cows	24.0	2.5	12.5	0.40	15.40	1:5.4
6. Fattening steers, 1st period	27.0	2.5	15.0	0.50	18.00	1:6.5
Fattening steers, 2nd period	26.0	3.0	14.8	0.70	18.50	1:5.5
Fattening steers, 3rd period	25.0	2.7	14.8	0.60	18.10	1:6.0
7. Fattening sheep, 1st period	26.0	3.0	15.2	0.50	18.70	1:5.5
Fattening sheep, 2d period	25.0	3.5	14.4	0.60	18.50	1:4.5
8. Fattening swine, 1st period	36.0	5.0	27.5		32.50	1:5.5
Fattening swine, 2d period	31.0	4.0	24.0		28.00	1:6.0
Fattening swine, 3rd period	23.5	2.7	17.5		20.20	1:6.5
9. Growing cattle:						
Age, Months. — *Average live weight per head.*						
2–3 — 165 lbs	22.0	4.0	13.8	2.0	19.8	1:4.7
3–6 — 330 lbs	23.4	3.2	13.5	1.0	17.7	1:5.0
6–12 — 550 lbs	24.0	2.5	13.5	0.6	16.6	1:6.0
12–18 — 770 lbs	24.0	2.0	13.0	0.4	15.4	1:7.0
18–24 — 940 lbs	24.0	1.6	12.0	0.3	13.9	1:8.0
10. Growing sheep:						
5–6 — 62 lbs	28.0	3.2	15.6	0.8	19.6	1:5.5
6–8 — 73 lbs	25.0	2.7	13.3	0.6	16.6	1:5.5
8–11 — 84 lbs	23.0	2.1	11.4	0.5	14.0	1:6.0
11–15 — 90 lbs	22.5	1.7	10.9	0.4	13.0	1:7.0
15–20 — 95 lbs	22.0	1.4	10.4	0.3	12.1	1:8.0
11. Growing fat pigs:						
2–3 — 55 lbs	42.0	7.5	30.0		37.5	1:4.0
3–5 — 110 lbs	34.0	5.0	25.0		30.0	1:5.0
5–6 — 137 lbs	31.5	4.3	23.7		28.0	1:5.0
6–8 — 187 lbs	27.0	3.4	20.4		23.8	1:6.0
8–12 — 275 lbs	21.0	2.5	16.2		18.7	1:6.5

The American ration for milch cows proposed by the the writer (see p. 91 of this report) is given below, and is recommended in preference to the standard ration for milch cows in the above table, as it is the outcome of the practical experience of successful dairymen and feeders in this and other states of the Union:

American standard ration for milch cows (per 1000 lbs. live weight).

Total organic matter	25.0 lbs.
Digestible protein	2.2 lbs.
Digestible carbohydrates	13.1 lbs.
Digestible fat	.7 lbs.
Total digestible matter	16.0 lbs.
Nutritive ratio	1:6.8 lbs.

An example will readily explain the manner in which the above tables may be used. Supposing we have at our disposal the following common feeding stuffs: fodder corn, clover hay, and bran, and that we wanted to know how much is required to keep a milch cow of 1,000 lbs. live weight in good condition and to secure a maximum yield of milk. Our feeding standard for milch cows calls for 25.0 lbs. of total organic matter, 2.2 lbs. of digestible protein, 13 lbs. digestible carbohydrates, etc., and a nutritive ratio of 1:6.8. The composition of the mentioned feeding stuffs will be seen from table I. We will feed 14 lbs. of fodder corn, 6. lbs. of clover hay and 10 lbs. of bran. According to Table I, these quantities contain the following number of pounds of digestible matter:

	Organic matter.	DIGESTIBLE.		
		Protein.	Carbo hydrates.	Ether extract.
	Lbs.	Lbs.	Lbs	Lbs.
14 lbs. of field-cured fodder corn	9.35	.36	5.38	.18
6 lbs. clover hay	4.71	.39	2.09	.10
10 lbs. bran	8.24	1.26	4.41	.29
Total	22.30	2.01	11.88	.57

This ration falls short of the feeding standard as regards both total organic matter and digestible substances. To bring it nearer to the standard, we shall have to add a couple of pounds of some concentrated feed. In selecting the foods and deciding the quantities to be given in each case, the market prices of the feeds must be considered.

We will suppose that a lot of corn meal is available in this case, and will add two pounds of this feed to the above ration:

	Organic matter.	Digestible.		
		Crude protein.	Carbohydrates.	Ether extract.
	Lbs.	Lbs.	Lbs.	Lbs.
Ration as above	22.30	2.01	11.88	.57
2 lbs. of corn meal	1.75	.14	1.25	.08
Total	24.05	2.15	13.13	.65
American feeding standard for milch cows	25.0	2.2	13.1	.7
Wolff's feeding standard for milch cows	24.0	2.5	12.5	.4

The ration now corresponds very well with the American feeding standard; there is a small deficit of organic matter, and of digestible protein and digestible fat, but, as explained in another place in this report (p. 89). there is no necessity of trying to follow any standard ration blindly, as they are only intended to be approximate gauges which the farmer may use in estimating the quantities of nutrients required by farm animals in order to do their best, cost and product both being considered.

In constructing rations according to the above feeding standards, several points must be considered besides the chemical composition and the digestibility of the feeding stuffs; the standards cannot be followed directly without regard to the bulk and other properties of the fodders; the ration must not be too bulky, and still must contain a sufficient quantity of coarse fodder to keep up the rumination of the fodders, in case of cows and sheep, and to secure a healthy condition of the animals generally.

Further, as chemical analysis of feeding stuffs is of necessity very crude, giving only certain groups of nutritive components, it does not reveal the inner qualities of a plant as a fodder. For instance, the plant might con-

tain a minute quantity of alkaloids or other poisonous substances, the presence of which chemical analysis, as now generally applied to fodders, does not tell, and the plant as a consequence would not only be valueless as a fodder, but injurious to the health of the animal. This is only one of many reasons why the feeding standards and the information we gather from the composition of the fodders cannot be taken as our only guide in the feeding of farm animals. Practical experience should go hand in hand with scientific knowledge; when this is the case, the information which may be derived from the above tables cannot help being most valuable to the feeder in aiding him to conduct his business on a rational systematic basis.

EXCHANGES.

The Station takes pride in the fact that it has on file an almost complete list of the leading agricultural papers in the United States, besides several from foreign countries, and some not strictly treating of agriculture. These papers come to the Station in exchange for its reports and bulletins. While of the highest value to those connected with the Station as the expression of agricultural experience and sentiment, they are placed where they can be read and referred to by the agricultural students and others of the University, as well as by visitors. Any one desiring sample copies of these papers can secure them upon application to the publishers, at the addresses herewith given.

FOREIGN EXCHANGES.

Aakerbruket och Husdjursskoetseln, Kalmar, Sweden.

Agricultural Gazette, London, England.

Australian Ironmonger, Melbourne, S. Australia.

Bell's Weekly Messenger, London, England.

Bulletin Des Seances de la Societe Nationale D'Agriculture de France, Paris, France.

Canadian Livestock and Farm Journal, Toronto, Canada.

Chronique Agricole du Canton de Vaud, Lausanne, Switzerland.

Extrait des Travaux de la Soc. Centr. d'Agr. de la Seine Infer., Rouen, France.

Farmer's Advocate, London, Ontario.

Fuehling's Landwirthschaftliche Zeitung, Leipsic, Germany.

Illustrated Journal of Agriculture, Montreal, Canada.

Journal für Landwirthschaft, Berlin, Germany.

Journal d'Agriculture Illustré, Montreal, Canada.

Journal of the British Dairy Farmers' Ass'n, London, Eng.

Journal of Royal Agricultural Society of England, London, Eng.

Kgl. Landtbruks-Akademiens Handlingar och Tidskrift, Stockholm, Sweden.

Landwirthschaftliche Wochenblatt, Kiel, Germany.
Le Messager Agricole, Paris, France.
L'Industrie Laitiere, Paris, France.
Live Stock Journal, London, England.
Live Stock and Farm Journal, Toronto, Canada.
Maritime Agriculturist, Dorchester, N. B.
Milch-Zeitung, Bremen, Germany.
Neue Zeitschrift für Rübenzucker-Industrie, Berlin, Germany.
North British Agriculturist, Edinburgh, Scotland.
Revue Internationale des Falsifications, Amsterdam, Holland.
Rural Canadian, Toronto, Canada.
The Analyst, London, England.
The Dairy, London, England.
The Field, London, England.
The Nor'West Farmer, Winnipeg, Manitoba.
The Scottish Farmer, Glasgow, Scotland.
Tidsskrift for Landoekonomi, Copenhagen, Denmark.
Ugeskrift for Landmaend, Copenhagen, Denmark.
Ulster Agriculturist, Belfast, Ireland.
Weekly Times, Melbourne, Australia.
Zeitschrift für Nahrungsmittel-Untersuchung und Hygiene, Vienna, Austria.
Zeitschrift des Landw. Vereins in Bayern, Munich, Germany.

DOMESTIC EXCHANGES.

Acker und Gartenbau Zeitung, Milwaukee, Wis.
American Agriculturist, New York. N. Y.
American Creamery, Chicago, Ill.
American Cultivator, Boston, Mass.
American Dairyman, New York, N. Y.
American Grange Bulletin, Cincinnati, O.
American Homestead, Omaha, Neb.
American Sheep-Breeder and Wool Grower, Chicago, Ill.
American Swineherd, Chicago, Ill.
Boston Weekly Globe, Boston, Mass.
Breeder's Gazette, Chicago, Ill.
Bulletin of the American Devon Cattle Club, Wheeling, W. Va.
California Cultivator and Poultry Keeper, Los Angeles, Cal.
Connecticut Farmer, Hartford, Conn.
Creamery and Dairy, Clarksville, Iowa.
Creamery Journal, Waterloo, Iowa.
Dairy Messenger, Chicago, Ill.
Detroit Free Press, Detroit, Mich.

Der Deutsch-Amerikanische Müller, Chicago, Ill., and New York City.
Drainage and Farm Journal, Indianapolis, Ind.
Elgin Dairy Report, Elgin, Ill.
Farm and Fireside, Philadelphia, Pa., and Springfield, Ohio.
Farm and Home, Springfield, Mass., and Chicago, Ill.
Farmers' Home, Dayton, Ohio.
Farm, Field and Fireside, Chicago, Ill.
Farm Journal, Philadelphia, Pa.
Farmer's Review, Chicago, Ill.
Farm, Stock and Home, Minneapolis, Minn.
Garden and Forest, New York, N. Y.
Geflügel Züchter, Wausau, Wis.
Grange News, Old Harmony, Ill.
Hoard's Dairyman, Ft. Atkinson, Wis.
Holstein Friesian Register, Brattleboro, Vt.
Home and Farm, Louisville, Ky.
Hospodar, Omaha, Neb.
Indiana Farmer, Indianapolis, Ind.
Industrial American, Lexington, Ky.
Industrialist, Manhattan, Kas.
Iowa Homestead, Des Moines, Iowa.
Jersey Bulletin, Chicago, Ill.
Kansas Farmer, Topeka, Kas.
Live Stock Indicator, Kansas City, Mo.
Live Stock Report, Chicago, Ill.
Lodi Valley News, Lodi, Wis.
Louisiana Planter, New Orleans, La.
Manitowoc Tribune, Manitowoc, Wis.
Mirror and Farmer, Manchester, N. H.
National Provisioner, New York, N. Y.
National Stockman, Pittsburg, Pa.
Nebraska Farmer, Lincoln, Neb.
New England Farmer, Boston, Mass.
New England Homestead, Springfield, Mass.
Northwestern Agriculturist, Minneapolis, Minn.
Northwestern Farmer, St. Paul, Minn.
Ohio Farmer, Cleveland, Ohio.
Orange Judd Farmer, Chicago, Ill.
Pacific Rural Press, San Francisco, Cal.
Practical Farmer, Philadelphia, Pa.
Prairie Farmer, Chicago, Ill.
Rural Life, Waterloo, Iowa.
Sheboygan County News, Sheboygan Falls, Wis.
Skördemannen, Minneapolis, Minn.

Southern Cultivator, Atlanta, Ga.
Southern Live Stock Journal, Starkville, Miss.
St. Croix Republican, New Richmond, Wis.
Sugar Beet, Philadelphia, Pa.
Texas Farm and Ranch, Dallas, Texas.
The Farmer's Institute, Mason City, Iowa.
The Husbandman, Elmira, N. Y.
United States Miller, Chicago, Ill., and Milwaukee, Wis.
Vick's Illustrated Monthly Magazine, Rochester, N. Y.
West American Scientist, San Diego, Cal.
Western Agriculturist and Live Stock Journal, Chicago, Ill.
Western Farmer and Stockman, Sioux City, Iowa.
Western Garden and Poultry Journal, Des Moines, Iowa.
Western Resources, Nincoln, Neb.
Western Rural, Chicago, Ill.
Western Stockman and Cultivator, Omaha, Neb.
Western Swineherd, Genesee, Ill.
Wisconsin Agriculturist, Racine, Wis.
Wisconsin Farmer, Madison, Wis.
Wisconsin Weather and Crop Journal, Milwaukee, Wis.
Wool and Hide Shipper, Chicago, Ill.
Wool and Mutton, Minneapolis, Minn.

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Australian Wools:

Through J. M. Peck & Son, Melbourne, Australia:

Nineteen samples from Sanders, James & Co., Canowia, Australia;

Sample and Photographs from A. J. Murray, Mt. Crawford, Adelaide, S. A;

Eleven samples from Alexander Sloane.

Through D. E. Eartin, Secretary for Agriculture, Victoria:

Four samples from J. Sanderson & Co., Brie Brie Station;

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Six samples from Sir W. Clark, Bolinda Vale;

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Six samples from A. E. Mansell, Harrington Hall, Shifnal, Eng.;
Sample Wensleydale from C. M. Brown, Narmby, Yorkshire, Eng.;
Sample Wensleydale from W. E. Long, Kent, Eng
Sample Exmoor from Wm. Oatway, Somerset, Eng.;
Three samples Exmoor from R. L. Stranger, Devon, Eng ;
Three samples Romney Marsh, W. E. Long, Kent, Eng.;
Samples showing English Classification of a fleece, from Fred M. Meade & Co., Ferersham, Eng.;
Two samples Suffolk from Colonial College, Suffolk, Eng.;
Sample Suffolk from James Smith, Suffolk, Eng.;
Twelve samples Rambouillet from M. VonBehr, Schmoldow, Germany

Canadian Wools:

Two samples Suffolk and Hampshire from Prof. Shaw, Guelph, Ont.;
Three samples Southdown from John Jackson & Sons, Abington, Ont.;
Sample Leicester from J. S. Smith, Maple Lodge, Ont.;
Samples Oxford Down from Henry Arkell, Guelph, Ont.;

American Wools:

Fifteen samples Southdown from Wm Watson, Turlington, Neb.;
Two samples Southdown, two samples Oxford from Geo. McKerrow Sussex, Wis;
Sample McDowell ram from W. A. Barber, Waldo, Wis.
Sample Dickinson Merino from Edgar Boenig, Hustisford, Wis.;
Sample Dickinson Delaine from D. M. Cunningham, Burlington, Wis.;
Sample Rambouillet from H. O. Bagley, Caldwell, Wis.;
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Two samples American Merino from A. F. Kelsey, Ionia, Mich.;
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HERD BOOKS.

Holstein Friesian Advanced Register, Vol. IV.,
S. Hoxie, Sup., Yorkville, N. Y.

Davy's Devon Herd Book, Vol. XV.,
John Risdon, Jr., Sec., Wiveliscombe, Somerset, England.

American Merino Sheep Register, Vol. II.,
A. H. Craig, Sec., Caldwell, Wis.

The Clydesdale Stud Book, of Canada, Vol. V.,
Henry Wade, Sec., Toronto, Can.

American Rambouillet Record, Vol. I.,
Samuel D. Pierson, Sec., Ixonia, Mich.

Record of Victoria Swine, Vol. I.,
H. Davis, Sec., Dyer, Indiana.

Register of the New York State Amer'n Merino Sheep Assn., Vols. I. & II,
John P. Ray, Hemlock Lake, N. Y.

The American Galloway Herd Book, Vol. IV.,
L. P. Muir, Sec., Independence, Mo.

Herd Register of the American Jersey Cattle Club, Vols. XXXV & XXXVI, J. J. Hemingway, Sec., New York City.

The American Cotswold Record, Vol. V.,
George Harding, Waukesha, Wis.

Record of Todd's Improved Chester-White Swine, Vol. IV,
Carl Friegau, Editor, Dayton, Ohio.

American Shropshire Sheep Record, Vols. VI. & VII,
Mortimer Levering, Sec., LaFayette, Ind.

Register of the Ohio Spanish Merino Sheep Breeder's Assn., Vol. I,
Capt. J. G. Blue, Sec., Cardington, Ohio.

American Devon Record, Vol. V,
L. P. Sisson, Sec., Wheeling, W. Va.

The Register of the Vermont Atwood Merino Sheep Club, Vol. I,
Geo. Hammond, Sec., Middlebury, Vt.

American Cleveland Bay Stud Book, Vols., I & II,
R. P. Stericker, Sec., Springfield, Ill.

American Hereford Record, Vol. XII,
C. R. Thomas, Independence, Mo.

English Jersey Cattle Society, Vol. VIII,
Joshua Le Gros, Sec., St. Helier, Jersey Isle.

The Clydesdale Stud Book, Vol. XIV, and Index to Vols. I–XII,
Robt. MacLehose, Glasgow, Scotland.

American Aberdeen-Angus Breeder's Assn., Vol. IV,
Thos. McFarland, Sec., Harvey, Ill.

The Hampshire Down Flock Book, Vols II & III,
Jas. Edward Rawlence, Sec , Salisbury, England.

The Oxford Down Flock Book, Vol. IV,
R. Henry Rew, Sec., Norfolk House, Norfolk St , London.

English Guernsey Cattle Society's Herd Book, Vol. VIII,
Julian Stephens, Sec., London.

The Chester White Record, Vol. II, and

Central Poland China Record, Vol. XII,
W. H. Morris, Sec., Indianapolis, Ind.

American Branch of the North Holland Herd Book, Vol. III,
Fred H. Beach, Sec., Dover, N. J.

Ohio Poland China Record, Vol. XIV,
Carl Freigau, Sec., Dayton, Ohio.

American Short Horn Herd Book, Vol. XXXVII,
J. H. Pickrell, Sec., Chicago, Ill.

British Berkshire Herd Book, Vol. VIII,
Heber Humfrey, Sec., Shippon, Abingdon, England.

North Holland Herd Book, Vol. III,
Fred H. Beach, Sec., Dover, N. J.

Red Polled Herd Book, Vol. IV,
J. McLain Smith, Sec., Dayton, Ohio.

Wensleydale Long Wool Sheep Breeder's Flock Book, Vol. I, II & III,
T. J. Other, Sec., Howgrave, Ripon.

FINANCIAL STATEMENT.

The Wisconsin Agricultural Experiment Station, in Account with the United States Appropriation.

1892.	Page.	Cr.	Dr.
To receipts from Treasurer of the United States, as per appropriation for the year ending June 30th, 1892, under act of Congress, approved Ma1ch 2d, 1887	11	....	$15,000 00
By salaries	24	$6,800 00	....
By labor	34	3,909 16	....
By laboratory supplies	44	27 60	....
By farm supplies	54	159 02	....
By freight and express	64	23 97	....
By postage and office supplies	74	209 00	....
By library	84	450 51	....
By farm implements	94	27 12	
By apparatus	104	295 15	....
By furniture	114	....	....
By fencing and drainage	124	....	....
By seeds and plants	134	78 22	....
By live stock	144	501 80	....
By feed	154	1,078 24	....
By traveling	164	157 02	....
By fuel and light	174	474 19	....
By incidental expenses	184	....	....
By building and repairs	194	749 00	....
		$15,000 00	$15,000 00

I hereby certify that the foregoing statement is a true copy from the books of account of the institution named.

E. F. RILEY,
Secretary Board of Regents,
University of Wisconsin.

MADISON, WISCONSIN, August 17, 1892.

APPENDIX.

TABLES GIVING DETAILED DATA OBTAINED IN SHEEP FEEDING EXPERIMENTS REPORTED ON PAGES 9—41.

22—Ex.

SHEEP FEEDING EXPERIMENT: FEEDING GRAIN TO LAMBS BEFORE WEANING.

TABLE I—*Showing gain of lambs in Lot I, in which the ewes were fed grain and pasture, and the lambs grain.*

No. of Lambs.	No. 497. * Born Mar. 17 Twin with No. 498.	No. 498. *	No 1028 * Born April 3. Twin with No.1027	No 1027 *	No. 475. * Born Apr. 13. Twin with No.1044	No.1044 *	No. 474. * Born Mar. 21. Twin with No.1008	No.1008 *	No. 367. ‡ Born Mar. 25.	No.1039 ‡ Born Apr. 21.	No.1013 † Born Mar. 31.	No. 219. * Born Mar. 14.	No. 369. § Born Mar. 27.	No. 217. * Born Mar. 9.	Total gain during period of ten weeks.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	L s.	Lbs.	Lbs.	Lbs.
Weight at beginning, April 26.. ...	17½	25	15½	20	10½	12¼	25½	16¼	20½	10	20½	31¼	30½	38	....
Weight at ending, July 5........ ...	41	49	48	51	42½	44	53½	46½	44½	39	51	65	76½	74	....
Gain of each lamb during 10 weeks	23½	24	32½	31	32	31¾	28	30¼	24	29	30½	33¾	46	36	432.25

* Shrop. grade. † Shrop-Merino. ‡ Southdown-Merino grade. § Dorset grade. Average weekly gain of each lamb 3.08 lbs.

TABLE II—*Showing gain of lambs in Lot II, in which ewes received pasture and no grain, and the lambs grain.*

No. of lamb.	No.1021 § Born Mar. 30. Twin with No.1022	No 1022 §	No.1006 § Born Mar. 18. Twin with No.1007	No 1007 §	No. 499. * Born Mar. 17. Twin with No. 500.	No. 500. *	No.1005 * Born Mar. 24. Twin with No. 366.	Nc. 366. *	No. 148. Born Apr. 20.	No. 403. § Born Mar. 21.	No. 375. * Born Apr. 10.	No.1015 * Born Mar. 28.	No.1016 * Born Mar. 21.	No. 374. * Born Mar. 11.	Tot l gain during period of ten weeks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.
Weight at beginning, April 27	20½	18	30	28½	22¾	28	25¾	21	12¾	19¾	14½	29½	36	32¼	.... ..
Weight at ending, July 6...........	55½	48½	68½	64	56	61¼	49	48	47½	53	39½	69½	72½	57	....
Gain of each lamb during 10 weeks	35	30½	38½	35½	33¼	33¼	23¼	27	34¾	33¼	25	40	36½	24¾	450½

§ Dorset grade. * Shropshire grade. Average weekly gain of each lamb, 3.2 lbs.

TABLE III.—*Showing gain of lambs in Lot III, in which ewes received pasture and grain and the lambs no grain.*

No of Lambs.	No. 1035 § Born April 7. Twin with No. 1036	No. 1036 §	No. 448 * Born Mar. 23 Twin with No. 1014	No. 1014 *	No. 1031 * Born Apr. 6. Twin with No. 1032	No. 1032 *	No. 1002 * Born Mar. 28. Twin with No. 1001	No. 1001 *	No. 1228 ‡ Born Mar. 21.	No. 402 § Born Mar. 23.	No. 216 * Born Feb. 26.	No. 1017 * Born Mar. 27.	No. 1025 ‡ Born Apr. 3.	No 489 ‡ Born Mar. 15.	Total gain during period of ten weeks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, April 28.. ...	15	14	18½	22	16¾	14¼	18	19¾	29½	25¼	36¾	28	20½	29	....
Weight at ending, July 7...........	42½	40½	48	47	40½	33½	44	47½	60½	55	65½	62	50½	66	....
Gain of each lamb during 10 weeks	27½	26½	29½	25	23¾	19¼	26	27¾	31	29¾	28¾	34	30	37	395¾

§ Dorset grade. * Shrop. grade. ‡ Southdown Merino grade. Average weekly gain of each lamb, 2.82 lbs.

TABLE IV.—*Showing gain of lambs in lot IV, in which ewes received pasture and no grain and the lambs no grain.*

No. of Lambs.	No. 488 § Born Mar 14. Twin with No. 376	No. 376 §	No. 1024 § Born Mar. 30. Twin with No. 1023	No. 1023 §	No 1010 § Born Mar. 21. Twin with No. 390	No. 390 §	No. 1029 * Born Apr. 3. Twin with No. 1030	No 1030 *	No. 1012 * Born April 1.	No. 1026 ‡ Born April 3.	No. 1011 * Born Mar. 20.	No 1019 ‡ Born Mar. 23.	No. 1004 * Born Mar. 22.	No. 1042 * Born April 28	Total gain during period of ten weeks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, April 29......	22¾	22	25	18½	24½	23¾	23½	21	24½	23	21½	26	30½	12¼	....
Weight at ending, July 8	46	47	58	39½	59	58½	50	46	56	59½	39½	43	64	48½	....
Gain of each lamb during 10 weeks	23¼	25	33	21	34½	34¾	26½	25	31½	36½	18	17	33½	36¼	395¾

d Dorset grade *Shrop. grade. ‡ Southdown Merino grade. Average weekly gain of each lamb, 2.82 lbs.

TABLE V—*Showing loss of the ewes in Lot I in which the ewes were fed grain and pasture and the lambs grain.*

No. of Ewe.	No. 486.	No. 1227.	No. 441.	No. 16.	No 55.	No. 58.	No. 480.	No. 1219.	No. 1218.	No. 1221.	Gain (+) or Loss (—) during period of ten weeks.
Date.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Weight at beginning, April 26....	197	132	175	118	139	100	161½	127	149	148	....
Weight at ending, July 5..........	157	122½	171½	105	105	90	140	112	141	138½	... ...
Loss...............	40	9½	3½	13	34	10	21.5	15	8	9½	....
Fleece shorn weighing.........	8.9	7.9	6.3	13	9	8	8.4	6.9	8	6 7	....
Actual loss (—) or gain (+) in flesh	—31.1	—1.6	+2.8	—	—25	—2	—13.1	—8.1	—	—2.8	Total. —80.9

TABLE VI—*Showing loss of the ewes in Lot II, in which the ewes received pasture and no grain and the lambs grain.*

No. of Ewe.	No. 1225	No. 1229	No. 443.	No. 425.	No. 445.	No. 36.	No. 27.	No. 147.	No. 368.	No. 344.	Gain (+) or Loss (—) during period of ten weeks.
Date.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Weight at beginning, April 27....	151½	145	136	136	172	131	132	103	159	130	
Weight at ending July 6...	129	131½	120	131½	131	106	106½	93	136	116½	
Loss.......	22.5	13 5	16	4.5	41	25	25.5	10	23	13 5	
Fleece shorn weighing.......	8.6	0.8	9	7.2	11.2	9	9.2	5.8	6.2	7.9	
Actual loss (—) or gain (+) in flesh............	—13.9	—4.2	—7	+2.7	—29.8	—16	—16.3	—4.2	—16.8	—5.6	Total. —111.1

TABLE VII—*Showing loss of the ewes in Lot III, in which the ew received pasture and grain and the lambs no grain.*

No. of Ewe.	No. 37.	No. 322.	No. 435.	No. 1222.	No. 49.	No. 8.	No. 1226.	No. 426.	No. 447.	No. 442.	Gain (+) or Loss (—) during period of ten weeks.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight at beginning, April 28....	130½	135	180	155½	139	84	133	148	178	124	
Weight at ending, July 7	111	123½	170	139	131	84½	115	134½	160½	113	
Loss.....	19.5	11.5	10	16.5	8	+.5	18	13.5	17.5	11	
Fleece shorn weighing........	11.3	7.6	7.8	6 3	9.2	5.7	6.4	9.1	8.1	6.9	
Actual gain (+) or loss (—) in flesh.	—8.2	—3.9	—2.2	—10.2	+1.2	+6.2	—11.6	—4.4	—9.4	—4.1	Total. —46.6

TABLE VIII.—*Showing loss of the ewes in Lot IV. in which the ewes received pasture and no grain and the lambs no grain.*

No. of Ewe.	No. 69	No. 32	No. 25	No. 137.	No. 431.	No. 433.	No 446.	No. 473.	No. 427.	No. 429.	Gain + or loss — during period of ten weeks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight at beginning, April 29....	93½	110½	144½	109	129½	116	96½	151½	140	155	
Weight at ending, July 8....	85	98	134½	107½	111	101	94	127	132	128½	
Loss	8.5	12.5	10.0	1.5	18.5	15	2.5	24.5	8	26.5	
Fleece shorn weighing....	11	9.2	12.2	1.9	7.7	9.7	7.7	8.8	9.2	9.4	
Actual gain (+) or loss (—) in flesh.	+ 2.5	— 3.3	+ 2.2	+ .4	—10.8	—5.3	— 5.2	—15.7	+ 1.2	—17.1	Total. —45.9

TABLE IX.—*Showing food eaten by ewes and lambs aud the cost of it in grain feeding experiment No.* 1.

PERIOD.	LOT. I. Ewes, grain and pasture; lambs, grain			LOT II. Ewes pasture, no grain; lambs grain.		LOT III. Ewes, grain and pasture; lambs no grain.		LOT IV. Ewes pasture, no grain; lambs no grain.
	Ewes.		*Lambs.*	*Ewes.*	*Lambs.*	*Ewes.*		*Ewes.*
	Hay.	Grain.	Grain.	Hay.	Grain	Hay.	Grain.	Hay.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First week.........	208	66	29¾	325	32	210	68	233
Second week.......	256	70	81½	208¾	38	172½	70	221
Third week	182¾	70	39¼	162¾	38¾	159	70	171
Fourth week.......	110¼	70	31¼	114½	40½	81½	70	57½
Fifth week.........	51½	35	34	81	44½	84½	70	141¾
Sixth week....	113½	35	53½	67¼	5 ½	51¾	70	16
Seventh week. ...	......	35	45½	....	47½	....	60	....
Eighth week.......	....	35	51½	.. . .	55	....	35	....
Ninth week	....	15	61	....	66½	....	35	....
Tenth week........	.... ..	10	66	.. ..	70½	....	35	....
10 weeks	922	441	443¼	959¼	488¾	759¼	583	840¼

Valuing the refuse hay that was fed at $5 per ton, the oil meal in the grain mixture at $20 per ton, the ground corn at $14 per ton, and the bran at $12 per ton, the cost of food (exclusive of the pasture, which was the same for all) would be as follows: Lot I, $8.59; Lot II, $5.89; Lot III, $6.05; Lot IV, $2.10.

EXPERIMENT: COTTONSEED MEAL COMPARED WITH OIL MEAL FOR FEEDING LAMBS.

TABLE X.—*Showing weight of lambs and food eaten in experiment comparing cottonseed meal with oil meal for feeding lambs.*

	LOT I. (Oilmeal mixture.) *Pasture; 1 part oilmeal; 2 parts cornmeal.*							LOT II. (Cottonseed meal mixture.) *Pasture; 1 part cotton seed meal; 2 parts cornmeal.*						
Week ending—	No. 371.	No. 370.	No. 376.	No. 403.	No. 390.	Grain eaten weekly.	Total weekly gain.	No. 364.	No. 377.	No. 398.	No. 404.	No. 387.	Grain eaten weekly.	Total weekly gain.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
July 23........	71.5	68	66.5	45	47.5	26	23	79.5	59.5	53.5	57	39	20.5	23
July 30........	75.25	70	66.75	47.5	49	28	10	80	63.75	56	59.75	41.5	35	12.5
August 6........	76.50	75	72.5	53.	53	30.5	21.5	86	70	61.5	66	46	32	28.5
August 13........	78.50	76	77	56.75	55.5	42	13.75	85	71	60.5	67.25	46.5	40.5	.75
August 20........	80.5	81	81	62	59.5	46	20.25	87.5	77	64.5	72.5	50	45	21.25
August 27........	87	86	86.5	66	63.5	49	25	91	81.5	71.5	(died)	54	38.5	19.00
September	90	87.5	92	71	69	57	20.5	94	85	71.5	....	56.6	35	9.00
September 10 ..	93.5	91.5	96	77	72	48.5	20.5	98	91	75.5	....	59	28.5	16.5
September 17....	99	92.5	97	76	74	47.5	8.5	100	94	76.5	....	61.5	34	8.5
September 24....	98	93	96	77	76.5	58	2.0	96	94	76	....	62.5	37.5	3.5(loss)
						432.5	165.					Total...	346.5	135.5
	Average weekly gain of each lamb 3.30 lbs.							Average weekly gain of each lamb 2.95 lbs.						

EXPERIMENT: SHEARING WETHERS BEFORE FATTENING.

TABLE XI.—*Weights and gains of wethers in the experiment relating to shearing wethers before fattening them.*

	Lot I—Three wethers once shorn.				Lot II—Three wethers twice shorn.			
Week ending.	No. 449	No. 470	No. 476	Weekly gain or loss (—)	No. 364	No. 469	No. 472	Weekly gain or loss (—)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
November 11....	103	91	85	—11	*98	*88.5	*87	--1.5
November 18....	107.5	93.5	83.5	6.5	97.5	91	88.5	3.5
November 25 ...	111	92	82	.5	100.5	93 5	89.5	6.5
December 2......	117	87	86	5	103.5	96 5	94.5	11
December 9......	115.5	92.5	88.5	6.5	105.5	99.5	96.5	7
December 16.....	118	95.5	88	5	107	98.5	99	3
December 23.....	119	99	88.5	5	109.5	101.5	101	7.5
December 30....	120.5	106	87.5	7.5	109.5	105	103	5.5
January 6.......	122.5	112	93	13.5	109	106 5	109	7
January 13......	127	112.5	96	8	107	110	110	2.5
January 20......	129	115	96 5	5	107.5	115	113	8.5
January 27......	131	121	99.5	11	110	115	115.5	5
February 3......	133	128	102.5	12	115	121	115.5	11
February 10.. ..	134	129	101	.5	115	126	114.5	4
February 17.....	137	135	102.5	10.5	118.5	128	118.5	9.5
February 24.....	139	137	102	3.5	122	130	119	6
16 weeks..... ...	37	39	13	89	17.8	43.2	35	96

* Without fleece.

TABLE XII.—*Foods eaten by the wethers in the experiment relating to shearing wethers before fattening them.*

Week Ending.	Lot I—Three Wethers Shorn Once.			Lot II—Three Wethers Twice Shorn.		
	Corn Fodder.	Grain.	Roots.	Corn Fodder.	Grain.	Roots.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
November 11	27	6	23	33	10.5	42
November 18	37.75	8.75	19	46.5	10.5	42
November 25	28.5	9.5	28	44.25	10.5	42
December 2	26	9.25	26	52.75	10.5	42
December 9	42	10 5	21	58	10.5	42
December 16	44.5	10.5	28	50	10.5	42
December 23	41.5	9.25	28	52	10.5	42
December 30	36	10.5	28	48.5	10.5	24
January 4	36	14.5	21	45.5	15	21
January 11	41.75	18.5	21	45.25	20	21
January 18	40.5	22	21	43.5	20	21
January 25	38.25	23	21	43.25	25.5	21
February 3	38	23	21	44.5	21.5	21
February 10	34	22	21	36.5	22	21
February 17	38.25	20 25	21	41.25	25.25	21
February 24	41.75	17	21	41.50	21	21
16 Weeks	591.75	234.5	369	726.25	254.35	486

EXPERIMENT: FEEDING AND MARKETING LAMBS.

TABLE XIII.—*Showing grain eaten and gain made by lambs on grain feeding experiment during the first period: April 30th to July 9th.*

Date.	LOT I.—Lambs (3) fed grain mixture of 1 part bran, 1 part cornmeal, ¼ part oil meal.					LOT II.—Lambs (3) did not receive any grain.			
	No. 370 born Mar. 28.	No. 376 born Ap. 18.	No. 371 born Ap. 17.	Total weekly gain.	Grain eaten weekly	No 369 born Mar. 28	No. 367 born Mar. 24	No. 375 born Ap. 25	Total weekly gain.
1891.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
April 30.	23.5	16	16.5	......	....	22	21.5	18.5	....
May 7	29	20	22	15	.50	26	25.5	17.5	11
May 14	32.25	24.75	27	13	4.25	29.25	30	22	12.25
May 21	37	30.5	33.5	17	1.75	31.5	33	25.5	7.75
May 28	41	34.5	38.5	13	5.50	37.5	36	29	13.50
June 4	44.75	39.5	43.5	13.75	6.75	41.5	40	34	13
June 11	45.5	41.5	46.5	5.75	9.00	44	40	35.5	4
June 18	51.5	47.25	54	19.25	14.00	49.25	43.5	40	13.25
June 25	56.5	52	59	14.75	14.50	53	48	44	12.25
July 2	60	57	62.5	12	9.75	58.5	52	48.5	14
July 9	64	60	66.5	11	14.00	61.5	54	52	8.5
10 weeks gain.	40.5	44	50	134.5	80	38.5	32.5	33.5	109.5

TABLE XIV.—*Showing loss in weight of ewes that were the dams of the lambs on the grain feeding experiment during the first period: April 30th to July 9th.*

DATE.	LOT I.—Ewes that were the dams of the lambs fed grain. No. 1220.	No. 1229.	No. 1213.	Total weekly gain (†) or loss (—).	LOT II.—Ewes that were the dams of the lambs given no grain. No. 1216.	No. 1215.	No. 1227.	Total weekly gain (†) or loss (—)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
April 30	109	131	118	....	129	119	119	....
May 7	109	131	121	† 3	133	122	119	† 7
May 14	110	132	116	— 3	129	122	129	† 6
May 21	108	133	118	† 1	134	124	128	† 6
May 28	111	137	118	† 7	137	129	130	†10
June 4	107	129	117	—13	134	124	128	—10
June 11	107	124	115	— 7	130	122	125	— 9
June 18	108	130	121	†13	131	124	128	† 6
June 25	108	134	121	† 4	134	124	127	† 2
July 2	115	132	120	† 4	131	121	120	—13
July 9	104	129	117	—17	126	121	117	— 8
10 weeks	......	.. ..	.....	— 8				— 3
Ewes during period lost 8 lbs.					Ewes during period lost 3 lbs.			

TABLE XV.—*Showing grain eaten and gain made by lambs on grain feeding experiment during the second period; July 9th to November 19th.*

Date.	Lot I. Lambs (5) fed grain mixture 2 parts cornmeal 1 part oilmeal.							Lot II. Lambs (5) no grain.					
	No. 371	No. 370	No. 376	No. 403 born May 5.	No. 390 born April 23.	Total weekly gain.	Grain eaten weekly.	No. 369	No. 367	No. 375	No. 366 born March 22.	No. 388 born April 28.	Total weekly gain.
1891.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
July 9	66.5	64	60	36	38.5	......	....	61.5	54	52	61	35	....
July 16	66	65	61	41.5	42	10.5	13.5	55	54	53	60.5	36	—.5
July 23	71.5	68	66.5	45	47.5	23	26	60.5	54	55	64	38	13
July 30	75.25	70	66.75	47.5	49	10	28	62	56.25	55.75	65.5	40	8
August 6	76.5	75	72.5	53	53	21.5	30.5	62.5	60.75	55.5	68.75	42.5	10.5
												No. 401 substituted weight 52½ pounds.	
August 13	78.5	76	77	56.75	55.5	13.75	42	65.5	65.25	55	71.5	51	8.25
August 20	80.5	81	81	62	59.5	20.25	46	64	65	56	72	51	—.25
August 27	87	86	86.5	66	63.5	25	49	70	69.5	63	78	56	23.50
September 3	90	87.5	92	71	69	20.5	57	71.5	71.5	65.5	81	60	13
September 10	93.5	91.5	96	77	72	20.5	48.5	71.5	73.5	71	78.5	63.5	8.5
September 17	99	92.5	97	76	74	8.5	47.5	74	76	70.5	82.5	66	11

September 24	98	93	96	77	76.5	2.0	58	70	75.5	69	83	63	−8.5
October 1	101	95	95	77	84	11.5	59	71	77.5	70	86	65	9
October 8	95	98	99	83	84	6.0	58.5	75	82	69	87	68	11.5
October 15	98	102	102	88	87	19	60	73	82	72	90	69	5
October 22	99.5	104.5	106	89.5	95	17.5	63	74	83.5	71	90	70.5	3
October 29	101	108	113	91	100	18.5	57	81	87.5	78.5	93	74	25
November 5	102.5	112	115.5	93.5	101	11.5	58	82	91	80	95	75	−9
November 12	97.5	112	114	93.5	102	−5.5	58.5	79	89	75	95	76	9
November 19	93	112.5	115.5	95	102.5	−.5	55	80.5	89	75.5	93.5	74.5	−1
Nineteen weeks' gain	26.5	48.5	55.5	59	64	253.5	915	19	35	23.5	32.5	29.5	139.5

TABLE XVI.—*Showing weekly gain made by lambs on grain feeding experiment during the fattening third period: November 19 to February 25.*

WEEK ENDING.	LOT I—Lambs (4) fed grain previous to this period.					LOT II - Lambs (4) fed no grain previous to this period.				
	No. 370.	No. 376.	No. 403.	No. 390.	Total weekly gain.	No. 369.	No. 367.	No. 366.	No. 402.	Total weekly gain.
1891.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
November 19	112.5	115.5	95	102 5	....	80.5	89	93.5	74.5	... .
November 26	117	119 5	100	105	16	85	90	99	74.5	11
December 3	123	123.5	106	115	26	91	98	104	82	26.5
December 10...........	122.5	124	107	115	1	92.5	100	101	84	2.5
December 17........ ..	123	130	109	112	5.5	94	101.5	102	87	7.0
December 24...........	125	133.5	112	116.5	13	100	104	103	91	13.5
December 31......... ..	126	133.5	112.5	119	4	101	107	104.5	93.5	10
January 7...	127	138	115	122.5	11.5	103.5	112	106.5	95.5	9.5
January 14......... ..	130	140	120	122.5	10	107	115	104	97	5.5
January 21	135	143	121.5	130	17	112	121	108	102	20
January 28............	135	144	123	131.5	4	114.5	123	110.5	103	8
February 4..	138	149	126.5	132.5	12.5	117	129	111	104	10
February 11......... ...	140	151	129	135	9	120	131.5	113.5	108	12
February 18......	142.5	153	132.5	141	14	125	136	119	111	18
February 25......... ..	145 5	156.5	136	145	14	128	139	123	113	12
14 weeks' gain... .	33	41	41	42.5	157.5	47.5	50	29.5	38.5	165.5

TABLE XVII.—*Showing food eaten weekly by lambs on grain feeding experiment during the fattening or third period; Nov. 19 to Feb. 25.*

DATE.	LOT I Lambs (4) fed grain previous to fattening.			LOT II—Lambs (4) no grain previous to fattening.		
Week Ending	Grain: 2 parts oats 1 part corn, 1 part oil-meal.	Corn fodder.	Roots.	Grain, (similar to Lot I).	Corn fodder.	Roots.
1891.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Nov. 26	38	48.5	14	27	43.5	14
Dec. 3	42.25	56	14	34	53.5	14
Dec. 10	48	57	21	42	56.25	21
Dec. 17	35.5	53.5	28	43	54	28
Dec. 24	36.5	54	28	42	48	28
Dec. 31	37.5	52.5	28	37	48.25	28
Jan. 7	30	57.5	28	34	51.5	28
Jan. 14	33	56	28	35.5	45	28
Jan. 21	34.5	61	28	40	50.75	28
Jan. 28	47	50.5	28	42	45.5	28
Feb. 4	34	53	28	39	48	28
Feb. 11	37.5	49.5	28	42.5	43.5	28
Feb. 18	41.5	56.25	28	48.5	54.5	28
Feb. 25	39.5	56	28	41.5	46.5	28
14 weeks	534.75	761.25	357	548.	688.75	357

TABLE XVIII.—*Sugar Beets in Wisconsin, season* 1892.

(Alphabetically arranged according to counties.)

No.	Name of grower.	Postoffice.	County.	Date of Planting.	Date of Harvesting.	Soil.	Average wt. of beets.	Yield per acre.	Solids in juice.	Sugar in juice.	Purity coefficient.	Variety.
							Lbs.	Lbs.	Per ct.	Per ct.		
1	John B. Meyer... ...	Modena......	Buffalo...	May 17..	Oct. 27..	Blk. prairie loam.	1.28	......	16.90	13.80	81.7	Vilmorin II.
2	John B. Meyer.......	Modena.......	Buffalo...	May 17..	Oct. 27..	Blk. prairie loam.	1.15	......	18.60	15.30	82.2	Desprez.
						Average......	1.22	....	17.75	14.55	82.0	
3	H. N. Peterson.......	New Holstein.	Calumet..	May 23..	Oct. 27..	Loam..	1.68	36,590	17.46	14.11	80.7	Vilmorin I.
4	H. N. Peterson.......	New Holstein.	Calumet..	May 23..	Oct. 27..	Loam............	1.48	31,360	19.13	15.95	83.4	Kleinwanzleber.
						Average......	1.58	33,975	18.30	15.03	81.0	
5	Joseph Ruff	Bloomer......	Chippewa.	.. ..	....	Sandy loam	.93	18,820	19.50	16.46	84.4	Vilmorin II.
6	Joseph Ruff	Bloomer	Chippewa.	May 16..	Oct. 20..	Sandy loam	2.08	26,480	18.82	16.08	85.4	Desprez.
7	J. W. Thomas..... .	Chippewa F'ls	Chippewa.	May 18..	Oct. 29..	Light sandy loam	.93	57,935	17.12	14.86	86.8	Vilmorin II.
8	J. W. Thomas........	Chippewa F'ls	Chippewa.	May 18	Oct. 29..	Light sandy loam	2.23	51,250	16.28	13.73	84.3	Desprez.
9	J. W. Thomas...	Chippewa F'ls	Chippewa.	May 18..	Oct. 29..	Light sandy loam	1.18	37,730	14.56	11.77	80.3	Improved sugar beet
						Average	1.47	38,443	17.26	15.38	84.2	
10	L. Randall........ ...	Neillsville... .	Clark.....	June 21.	Oct. 20..	Loam............	.95	15,680	19.82	17.07	86.1	Vilmorin II.
11	L. Randall...........	Neillsville....	Clk	June 21.	Oct. 20..	Loam.	.95	23,230	20.06	17.32	86.3	Desprez.
						Average... ..	.95	19,455	19.94	17.19	86.2	

12	R. Hopkins	Leeds	Columbia.	June 7	Oct. 28	Prairie	3.08	....	18.18	8.23	62.5	Vilmorin I.
13	R. Hopkins	Leeds	Columbia.	June 7	Oct. 28	Prairie	2.78	....	17.00	12.77	75.2	Kleinwanzleben.
14	E. F. Russell	Poynette	Columbia.	May 26	Oct. 25	Sandy loam	1.83	52,267	17.00	14.41	84.8	Vilmorin I.
15	E. F. Russell	Poynette	Columbia.	May 26	Oct. 25	Sandy loam	1.38	43,560	17.92	15.81	88.2	Kleinwanzleben.
						Average	2.27	47,913	16.28	12.81	77.7	
16	S. Rudesill	Downing	Dunn	June 6	Oct. 8	Clay loam	.80	17,424	16.00	13.98	87.1	Vilmorin II.
17	S. Rudesill	Downing	Dunn	June 6	Oct. 8	Clay loam	.48	12,200	18.83	16.72	83.8	Desprez.
						Average	.64	14,812	17.41	15.38	88.0	
18	H. L. Clapp	Ripon	F. du Lac.	May 9	Oct. 14	B'ack prairie	1.55	....	19.82	16.39	82.7	Desprez.
19	H. L. Clapp	Ripon	F. du Lac.	May 9	Oct. 14	Black prairie	1.73	....	17.35	13.88	80.0	Kleinwanzleben.
20	H. L. Clapp	Ripon	F. du Lac	May 9	Oct. 14	Black prairie	1.15	27,879	16 66	13.19	71.1	Vilmorin I.
						Average	1.48	27,879	17.94	14.49	77.9	
21	H. Harbican	Big Patch	Grant.	June 11.	Oct. 10.	Timber clay	1.85	....	13.71	10.55	76.9	Vilmorin II.
22	John Elmer.	Browntown	Green	May 20	Oct. 22	Rich black soil	1.93	....	16 20	12.60	77.8	Kleinwanzleben.
23	Thos. Sears	Monticello	Green	May 20	Nov. 7	Sandy loam	.78	24,970	12.82	8.82	68.8	Vilmorin I.
24	Thos. Sears	Monticello	Green	May 20	Nov. 7	Sandy loam	.63	31,940	16 05	11.99	74.7	Kleinwanzleben.
25	J. W. Whitebear.	Twin Grove	Green	May 7	Sept. 15.	Blk. prairie loam.	.70	29,040	18.14	15.05	83.0	Kleinwanzleben.
						Average	1.01	28,650	15.80	12.12	76.1	
26	W. F. Sti es.	Lake Mills	Jefferson.	April 7	Oct. 22	Sandy loam	.80	....	15.98	12.56	78.6	White Imperial.
27	Alva Jaquith	Oak Hill	Jefferson.	May 28.	Oct. 17	Clay loam	1.83	29,620	17.12	13.75	80.3	Vilmorin I.
28	Alva Jaquith	Oak Hill	Jefferson.	May 28	Oct. 17	Clay loam	1.13	24,680	18.38	15.31	83.3	Kleinwanzleben.
29	J. Schoechert	Watertown	Jefferson.	April 8	Oct. 22	Light clay	2.05	66,200	15.28	12.47	81.6	Vilmorin I.
						Average	1.45	40,166	16.69	13.52	81.0	

Sugar Beets in Wisconsin, season 1892.– Continued.

No.	Name of Grower.	Post Office.	County.	Date of Planting.	Date of Harvesting.	Soil.	Av. wt. of beets.	Yield per acre.	Solids in juice.	Sugar in juice.	Purity coefficient.	Variety.
							Lbs.	Lbs.	Per ct.	Per ct.		
30	Chas. Boettcher......	Kewaunee ...	Kewaunee	May 28..	Oct. 22..	Black loam.......	4.4	113,260	15 86	12.29	77.9	Vilmorin I.
31	Chas. Boettcher......	Kewaunee. ..	Kewaunee	May 28..	Oct. 22..	Black loam	4.53	107,450	15.86	11.70	73.8	Grand Island.
32	John Jelinek, Jr......	Kewaunee....	Kewaunee	May 23.	Oct. 25..	Light clay.......	2.58	56,630	20.95	17.59	84.0	Vilmorin I.
33	John Jelinek, Jr......	Kewaunee....	Kewaunee	May 23..	Oct. 25..	Light clay........	2.13	48,790	21.82	18.90	66.6	Kleinwanzleben.
						Average......	3.41	81,531	18.62	15.12	80 5	
34	Thos. Martin..	Merrill	Lincoln...	June 11.	Oct. 17..	Clay loam	.43	23,230	22.50	19.71	87.6	Vilmorin II.
35	Thos. Martin	Merrill........	Lincoln...	June 11.	Oct. 17..	Clay loam........	.80	38,910	20.40	17.67	86 6	Desprez.
						Average.......	.62	31,070	21.45	18 69	87.1	
36	Henry C. Koch	Manitowoc. .	Manitow'c	May 24..	Oct. 26..	Sandy loam	1.53	56,000	18.60	17.37	88.0	Vilmorin I.
37	Henry C. Koch	Manitowoc . .	Manitow'c	May 24..	Oct. 26..	Sandy loam......	1.40	50,000	18.82	16.21	86.1	Kleinwanzeleben.
38	Thos. Mohr	Manitowoc ...	Manitow'c	May 25..	Oct. 15.	Black loam	1.15	30,580	16.16	13.03	81.0	Vilmorin I.
39	Thos. Mohr	Manitowoc ...	Manitow'c	May 25..	Oct. 15..	Black loam......	1.38	33,120	18.14	14.92	82 3	Kleinwanzleben.
						Average	1.36	42,425	17.93	15.13	84.4	
40	Aug. Schlaver, Jr ...	Sparta	Monroe...	May 5...	Oct. 27..	Light clay... ...	2.93	20,000	11.92	7.93	66.5	Kleinwanzleban.
41	E. E. Wyatt....	Tomah........	Monroe...	May 9...	Nov 12.	Sandy..........	2.35	19,425	15.62	11.98	76.7	Vilmorin I.
42	E. E. Wyatt	Tomah	Monroe...	May 9. .	Nov. 9..	Sandy	1.38	21,516	18.48	15.94	86.3	Kleinwanzleban.
						Average.......	2.22	20,318	15.34	11.95	76.5	

43	John Ericson	Kelly Brooks	Oconto	June 12	Nov. 2	Heavy loam	.70	8,116	19.16	16.77	87.6	Vilmorin II.
44	A. Mueller	Port Washington	Ozaukee	May 12	Oct. 19	Clay	2.28	....	17.80	14.84	83.4	Desprez.
45	Fred. Knaack	Porcupine	Pepin	June 4	Oct. 31	Heavy clay	4.08	27,880	20.18	17.31	85.8	Vilmorin II.
46	Geo. Trageser	Plover	Portage	April 20	Oct. 22	Sandy	1.90	....	18.82	15.26	81.1	
47	W. H. Carpenter	Aniwa	Shawano	June 13	Nov. 4	Loam	1.15	26,486	18.38	15.31	83.3	Vilmorin II.
48	W. H. Carpenter	Aniwa	Shawano	June 13	Nov. 4	Loam	1.03	26,835	19.16	15.69	81.9	
						Average	1.09	26,660	18.77	15.50	84.6	
49	N. Fischer	Plymouth	Sheboyg'n	May 16	Oct. 19	Black muck	8.53	68,244	19.38	14.51	74.9	Desprez.
50	Otto Schneider	Plymouth	Sheboyg'n	May 17	Oct. 30	Black muck	1.65	45,300	19.95	15.55	77.9	Desprez.
51	L. Knauer	Plymouth	Sheboyg'n	May 17	Oct. 25	Gravely clay	1.40	40,656	19.28	14.56	75.5	Desprez.
52	Otto Bergemann	Plymouth	Sheboyg'n	May 14	Nov. 11	Sandy loam	1.18	33,252	19.16	14.54	75.9	Desprez.
53	A. Ziegler	Plymouth	Sheboyg'n	May 12	Oct. 24	Heavy red clay	1.10	....	19.16	15.39	80.4	Desprez.
54	G. Schierstedt	Plymouth	Sheboyg'n	May 11	Oct. 17	Sandy loam	1.03	38,080	18.68	14.57	78.0	Desprez.
						Average	1.65	45,106	19.27	14.85	77.1	
55	Thos. Brehm	Che'sea	Taylor	June 4	Oct. 20	Garden soil	1.15	....	22.60	19.45	86.0	Vilmorin II.
56	Thos. Brehm	Chelsea	Taylor	June 4	Oct. 20	Garden soil	1.28	....	23.38	18.26	80.1	Desprez.
						Average	1.21	....	22.99	18.85	83.1	
57	H. Larson	Sharon	Walw'rth	June 13	Oct. 24	Clay loam	1.03	....	19.16	16.96	78.7	Kleinwanzleban.
58	C. D. Wolfram	West Bend	W'shg'ton	May 24	Oct. 25	Heavy clay	1.23	37,700	17.35	13.98	80.6	Vilmorin I.
59	C. D. Wolfram	West Bend	W'shg'ton	May 24	Oct. 25	Clay loam	1.70	41,880	17.46	14.35	82.2	Kleinwanzleban.
						Average	1.46	39,790	17.40	14.16	81.4	

Sugar Beets in Wisconsin, season 1892.—Continued.

No.	Name of Grower.	Post Office.	County.	Date of Planting.	Date of Harvesting.	Soil.	Av. wt. of beets.	Yield. per acre.	Solids in juice.	Sugar in juice.	Purity coefficient.	Variety.
							Lbs.	Lbs.	Per ct.	Per ct.		
60	Geo. W. Jones	Neenah	Win'eb'go	May 25	Oct. 22	Loam	1.23	33,110	18.48	16.10	87.1	Vilmorin II.
61	Geo. W. Jones	Neenah	Win'eb'go	May 25	Oct. 22	Loam	1.28	36,580	18.82	16.43	87.3	Vilmorin II.
						Average	1.25	34,845	18.65	16.26	87.2	
62	W. H. Reeves	Centralia	Wood	May 17	Sep. 26	Sandy loam	.83	14,157	19.73	17.18	87.1	Vilmorin II.

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